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SAFEPATH: Final report

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Call 2019 Safe Smart Highways

SAFEPATH: Final report

by

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The Programme Executive Board for this project included:

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Executive Summary

National Road Authorities (NRAs) are facing many challenges with growing congestion and the need to increase capacity, together with the demand for safety improvements, better quality information to meet the needs of drivers, and wider issues including environmental improvements such as air quality. This is with a backdrop of political, financial and operational opportunities and constraints, in a world in which technology is constantly evolving.

For several years, industry, academia, and road operators have been developing and evaluating measures to increase highway capacity – that is, to increase both maximum potential traffic flow (basic capacity), and the proportion of time for which the highway can deliver that maximum.

SAFEPATH – a consortium led by AECOM and including Royal HaskoningDHV, White Willow Consulting, and Eindhoven University of Technology – has conducted research to identify good practice on increasing capacity while improving safety through smart safe highways. The project is part of the CEDR 2019 (2) Research call.

This final report describes the project's management and execution, summarises deliverables, and assesses performance with respect to the original project specification.

Project management followed a proven approach, with an Advisory Group consisting of industry experts providing strategic guidance. Participants reported to the Programme Executive Board (PEB), made up of members of the organisations sponsoring this work.

Within SAFEPATH, task group *WP2000 System Analysis* dealt with stakeholder engagement and modelling the system, *WP3000 Empirical research* conducted the literature and stakeholder surveys into measures for increasing capacity, *WP4000 Road safety analysis* conducted road safety analysis of these measures, and *WP5000 The Practitioners' Guide* brought together work from *WP3000* and *WP4000* to compile The Practitioners' Guide to Safe Smart Highways.

WP6000 Final report dealt with final reporting, while *WP7000 Dissemination* forms the main work on disseminating the project's findings.

The project produced several formal reports, but the three primary external outputs included:

- The Practitioners' Guide to Safe Smart Highways
- The SAFEPATH measures database website
- The SAFEPATH-IIT Road safety Impact Indicator Tool

The project started with high ambition to engage end-users (for knowledge gathering), but this proved harder than initially expected. It was hard to engage NRAs beyond those who were already implementing capacity improvement measures. This was less of a problem in the initial, information-gathering stage, but more an issue for dissemination. However, this difficulty demonstrated the need for such a project to stimulate knowledge sharing.

SAFEPATH worked hard to build engagement momentum, and as a result much interest was shown in the final dissemination activities, showing the project has a strong potential legacy.

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1. Definition of the issue

National Road Authorities (NRAs) are facing many challenges with growing congestion and the need to increase capacity, together with the demand for safety improvements, better quality information to meet the needs of drivers, and wider issues including environmental factors such as air quality. This is with a backdrop of political, financial, and operational opportunities and constraints in a world where technology is constantly changing.

Industry, academia, and road operators worldwide have been developing and evaluating ways of safely enhancing the capacity of existing highways over many years. These solutions are particularly relevant to the many locations in which building-out new roads to provide for predicted increases in traffic is impractical.

Some nations, such as the Netherlands and the UK, have more mature solutions and as a result a useful knowledge resource which is of obvious interest and use to those who are seeking to understand and develop solutions to meet their own highway requirements. There are also further, some niche, measures that other countries have implemented.

This project aimed to share knowledge of schemes in practice, as there was no go-to place to find reliable evidence on measures which safely increase highway capacity.

Ultimately, this work aims to address the European Union's (EU) high-level goals, which include the improvement of quality of life for EU citizens.

1.1. Scope of the project

The project set out to collect evidence of working examples of measures adopted anywhere in the world, but particularly within Europe, intended to increase the capacity of highways without increasing their land take. This last condition is particularly important in the context of the nations of the European Union with their high population and infrastructure densities.

The over-arching objectives of this project were:

- To deliver guidance of real, practical use to NRAs.
- To provide consistent methodologies and analysis for ease of use and application.
- To follow an evidence-based approach to qualify project deliverables.
- To demonstrate the project outcomes are useable and sustainable for up to 5 years.

This project focused primarily on gathering good practice – for instance, measures to increase capacity that are well-evidenced. There are many measures that show high potential or theoretically increase capacity, but which have no strong evidence of capacity increases from real-world implementation.

Adding capacity to highways is at odds with actions of many city regions looking to reduce capacity for road vehicles and instead aiming to increase capacity for active travel modes.

Adding capacity to highways often leads to induced demand. This is very difficult to predict as there are many variables but should be considered as a risk. For instance, increasing capacity to relieve congestion, may lead to induced demand that eventually results in the original issue returning, or indeed congestion worsening on neighbouring roads.

This project builds on earlier work. For example, the safety aspect includes the goals of "CEDR Position Paper 2021: Road Safety – Towards the Vision Zero"[1] while the capacity work is linked

[1] Main Road Safety Challenges for European Road Directors the next 5-10 years – Towards the Vision Zero (4 November 2021) https://www.cedr.eu/docs/view/6183e651d28a8-en

to the SPINTRENDS | SPINDESIGN | SPADE project on Collaborative Planning[2]. The SAFEPATH project also liaised closely with the SHADAR[3] (Stopped vehicle hazards) project, which had been running concurrently.

This project does not include measures which rely solely upon in-vehicle technology, as the implementation of this technology lies beyond the remit of NRAs. It does not include the modelling of proposed measures to increase capacity, nor the wider issue of induced demand mentioned above. It also does not directly involve the implementation of new measures, or new work assessing measures already in place. It does not make recommendations for new or proposed schemes, but instead offers a toolkit to enable prospective schemes to be screened for applicability.

1.2. Project consortium

The project was carried out by a consortium from countries across Europe, and included voluntary input from NRAs, relevant industry organisations, and experts through an Advisory Group. The role of the Advisory Group was to provide impartial and real-world support to the overall direction, outcomes and outputs of the project. It is different from the PEB as it includes external stakeholders. The PEB has priority if any conflict occurs in such support.

AECOM acted as project coordinator and led the consortium. AECOM are an experienced advisor to NRAs with extensive smart motorway experience, strong project management skills, and successful research delivery on smart infrastructure solutions.

Royal HaskoningDHV are an experienced traffic management consultant and provide road safety analysis to assess road network performance for many European road operators.

Eindhoven University of Technology (TU/e) are a highly respected university with extensive safety analysis experience and regular participation in the delivery of many key European research projects.

White Willow is a consultant with a proven background in smart technology delivery and a strong understanding of the impact of connectivity and autonomy and the impact on safety and network performance including recent European studies.

1.3. Methodology of the project

The project was delivered by following key principles upholding these objectives. These principles were:

- Use of a ***systems engineering*** approach, recognising the range and complexity of factors which influence highway capacity and safety.

[2] Call 2017 Collaborative Planning Final Programme Report (11 May 2021) https://cedr.eu/docs/view/609a4ed6a495f-en

[3] SHADAR (stopped vehicle hazards): https://www.cedr.eu/download/other_public_files/research_programme/call_2019/safe_smart_highways/shadar/SHADAR-project-description.pdf),

- Clear ***problem definition and demarcation***, including measures and key performance indicators.
- A well-defined ***stakeholder engagement*** plan of interviews, workshops and questionnaires outlining who, when, what and why, to ensure sustained involvement, interest and ultimately a clear route for guidance dissemination and use.
- The development of a ***central database of measures*** and solutions, including current practice and safety reports, to provide a sustainable resource for others to use in future.
- A defined approach to assessing ***current safety analysis methods***, by road operators and wider industry, providing greater consistency for application.
- The collection of solutions and lessons learned to inform and support real-world applications for use within the delivered ***Practitioners' Guide***.

The structure and organisation of the project are depicted in Figure 1.

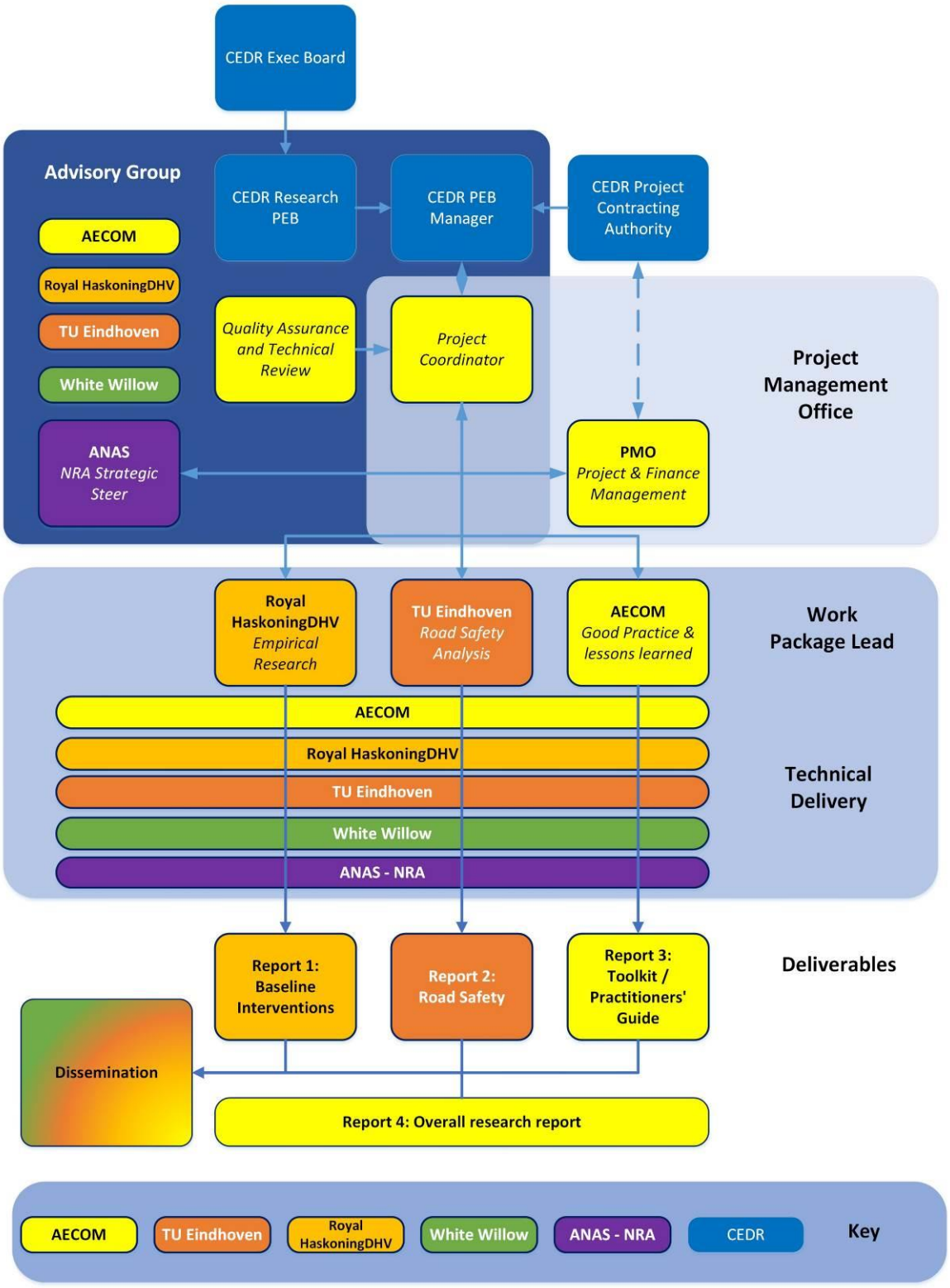

Figure 1 – Structure and organisation of the SAFEPATH project.

Figure 2 shows the composition of the project's three Phases and their timeline. The *Good Practice Guide* was eventually published as *The Practitioners' Guide to Safe Smart Highways* following feedback from potential end-users with regards to the interpretation of the words *good practice* in, for example, UK Law.

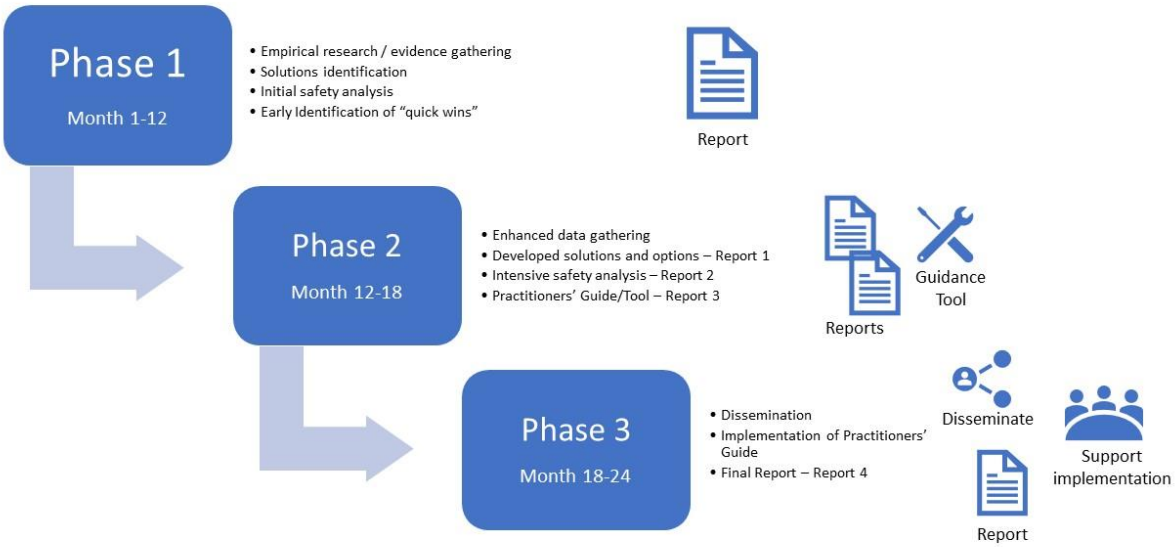

Figure 2 – Timeline of the project's three phases.

SAFEPATH used an agile approach, getting quickly to the end of Phase 2 by month 12. In this way it was able to share results with the PEB and stakeholders. This was particularly important as it allowed a further 12 months to build on their feedback.

Phase 2 essentially repeated Phase 1 but was more focused on targeted information.

This approach also helped speed up the dissemination, as it enabled the sharing of a finished piece of work with potential end-users, to give them an appetite for the final deliverable at month 24. They may not otherwise be able to factor in the work during their planning.

Dissemination of project results is often left to happen after the close of the project, which means it doesn't get enough attention, but we were able to incorporate it within the delivery schedule.

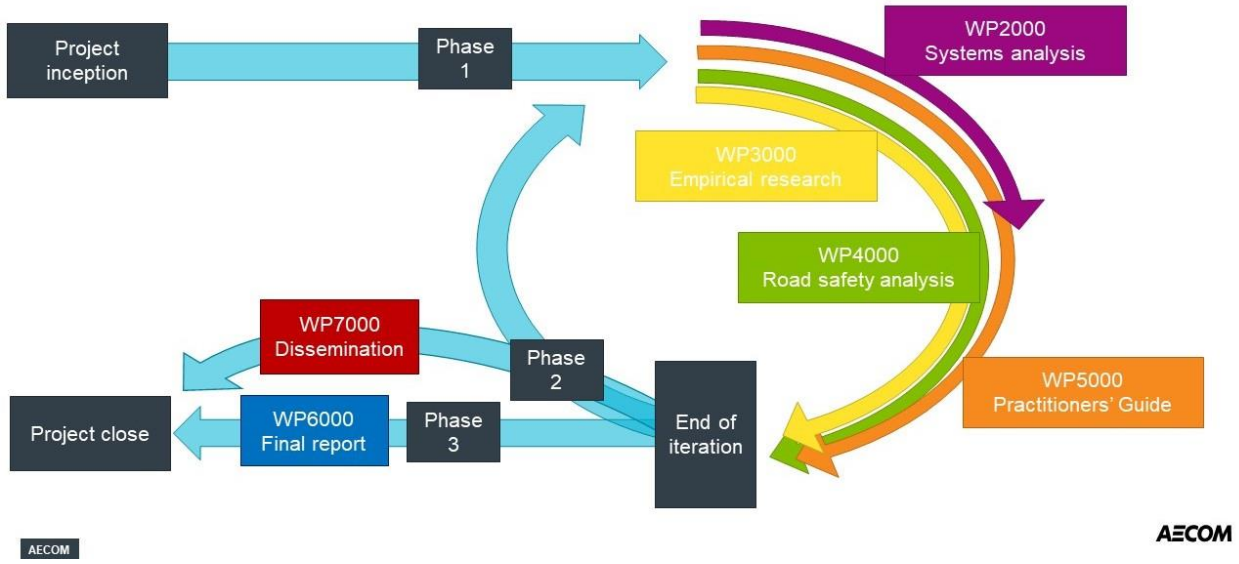

Figure 3 illustrates the agile approach of the SAFEPATH methodology. It also maps the Phases to the Work Packages.

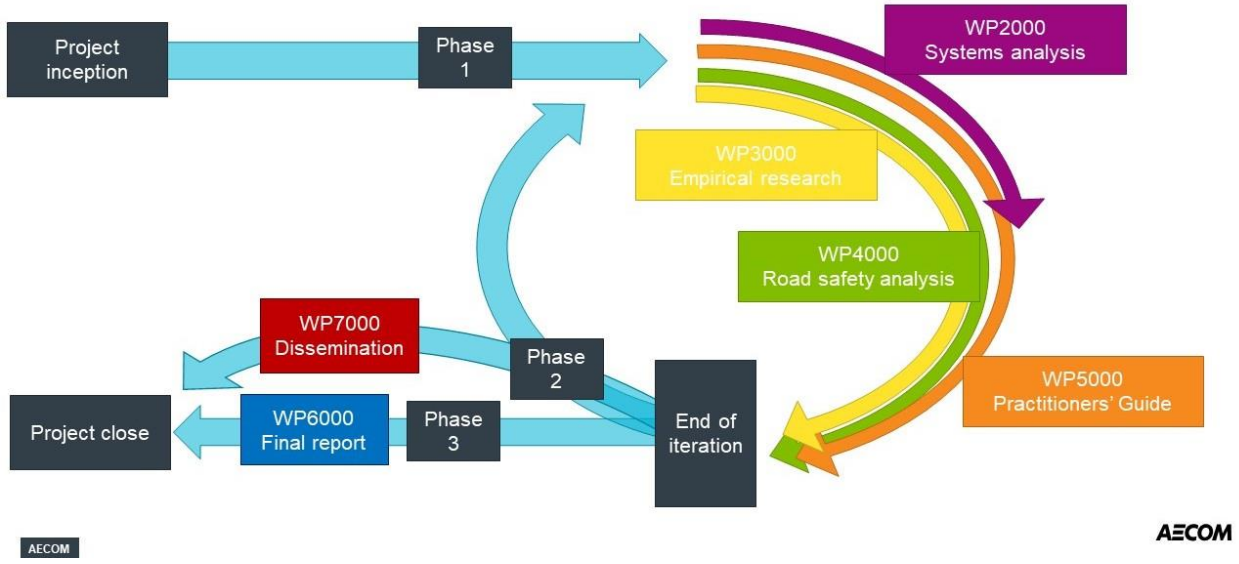

Figure 3 – Schematic of the chosen methodology, including work package numbers.

1.3.1. Phase 1

Phase 1 of SAFEPATH began after the project inception and continued until month 12. As shown in Figure 3, four work packages operated in parallel for the first six months, before WP2000 ended and the other three continued until month 12.

WP2000 Systems analysis outlined the framework within which this research project would operate. It used a methodical approach to understand the issue of highway capacity and road safety and provided the basis upon which the literature research was completed. This work package produced an interim technical report titled the ***Problem and systems analysis***.

WP3000 Empirical research used several methods to capture literature and knowledge related to safely increasing highway capacity based on the terms and definitions described in WP2000. This included a literature search of previous work by and for CEDR and other EU bodies and initiatives, NRA and other national government publications, academic literature, and feedback from stakeholder engagement to identify potential solutions. Search terms were taken from the Systems Analysis work of WP2000. Key repositories of literature included Google Scholar, Science Direct, Directory of Open Access Journals, SafetyLit, PsychInfo, Scopus, Social Science Citations Index, the Road Safety Observatory, and previous CEDR publications.

Potential solutions were assessed for their impact on both safety and capacity, and 'quick wins' were identified in an interim ***Solutions report***. Examples of such 'quick wins' include traffic management measures, notably *hard shoulder running*. However, there are mixed results around the safety of this measure depending on how it is deployed. *High-occupancy lanes* and *variable mandatory speed limits* were also found to offer capacity increases but appear to have less of an undesirable impact on safety.

A **Stakeholder engagement plan and tracker** were developed. The activities in the plan were relevant to multiple work packages, and included:

- Seminars with industry stakeholders, PEB members and NRA representatives.
- One-to-one interviews with NRA personnel, road user representative groups, vehicle manufacturers, and service providers.
- The distribution of questionnaires in lieu of an interview.
- Virtual workshops (typically with 10 participants each).
- Focus group style feedback workshop (with a high proportion of original stakeholders) to validate The Practitioners' Guide to Safe Smart Highways and support resources.
- A living online database of the measures identified in this project, available for project partners, steering NRAs and the PEB.
- Continuous engagement with stakeholders through multiple communications channels.

WP4000 Road safety analysis investigated the safety impact of the measures used to increase highway capacity. This involved a thorough review of the various methodologies used to assess safety impact. This work package produced an interim report titled ***Road safety analysis***.

WP5000 The Practitioners' Guide monitored the progress of the other work packages to capture relevant information considered good practice. This information was consolidated in an interim ***Good Practice Guide*** (later to be rename The Practitioners' Guide to Safe Smart Highways).

Information was only gathered on measures already in use. Some measures had no full follow-up study of their effectiveness, although these were nevertheless included in the SAFEPATH database. For some, where the measure was built-in from the start, comparison data would never have been available to gather. An example would be the A38 in the UK, where the road was constructed with the *tidal flow* reversible centre lane.

Towards the end of Phase 1, a ***Phase 2 plan*** was produced to outline the proposed work to expand the research and identify additional measures to include in the guide.

Deliverables completed as part of Phase 1 included:

- Monthly progress reports, PEB meetings at 6-month intervals, and Advisory Group meetings at 6-month intervals.
- Problem and systems analysis report (WP2000).

- Stakeholder engagement plan and tracker (WP3000).
- Interim Solutions report (WP3000).
- Measures database (WP3000).
- Interim Road safety analysis report (WP4000).
- Interim Good Practice Guide (WP5000).
- Phase 2 plan (WP5000).

1.3.2. Phase 2

As shown in Figure 3, Phase 2 involved a repeat cycle of the research methodology to identify further information about measures to safely increase highway capacity. This generally involved identifying new measures or diving deeper to find evidence related to measures already identified in Phase 1.

In a change to the original proposed approach and outlined in the Phase 2 plan, Phase 2 specifically completed further outreach to NRAs directly for information about measures they have tried, along with their findings and results, for increasing highway capacity safely. This was facilitated by sharing knowledge gathered during Phase 1. This enhanced engagement was recognised as valuable for both information gathering and generating momentum with participants for the dissemination of the project's final outputs during Phase 3.

Elsewhere throughout Phase 2, WP3000 and WP4000 completed further investigation into their respective areas. Additional reports were identified and reviewed to extract relevant content of The Practitioners' Guide.

Deliverables completed for Phase 2 included:

- Solutions report (WP3000).
- Updated measures database website (WP3000).
- Safety analysis report (WP4000).
- The Practitioners' Guide to Safe Smart Highways (WP5000).

1.3.3. Phase 3

By project design, Phase 3 involved a significant period of dissemination of project results. In actuality, the dissemination activities were started even before Phase 3 through the engagement of stakeholders and attendance at industry events. The publication of the Practitioners' Guide to Safe Smart Highways was advertised widely.

Phase 3 primarily involved **WP6000 Final** report and **WP7000 Dissemination**.

Phase 3 included the production of the ***SAFEPATH Final report*** (this document). As described in Section 2, this included a review of the project outputs and actions, the uptake of the project outputs, impact analysis, and identification of recommended future work.

This Phase involved the widespread dissemination of the SAFEPATH outputs. This is described in more detail in Section 2.4.7.

Deliverables completed as part of Phase 3 included:

- SAFEPATH Final report (WP6000).
- Dissemination of SAFEPATH outputs (WP7000).

2. Review of the project

2.1. Project outcomes compared to original objectives

The aim of the project was to consolidate measures of good practice related to increasing the capacity of highways while not compromising traffic safety.

The objectives to achieve this aim were introduced in Section 1.1. Table 1 describes how the SAFEPATH project outputs compared to the original objectives.

Table 1 – The SAFEPATH project objectives and how they were achieved.

SAFEPATH objective	SAFEPATH output
To deliver guidance of real, practical use to NRAs	SAFEPATH produced three useful outputs for practitioners to identify measures to increase highway capacity that may be relevant to them: • The ***Practitioners' Guide to Safe Smart Highways*** to provide an overview of well-evidenced measures. • The ***SAFEPATH measures database*** website providing easy access to the underlying research evidence. • The ***SAFEPATH-IIT*** (impact indicator tool) to assess the safety impact of measures.
To provide consistent methodologies and analysis for ease of use and application	The ***Practitioners' Guide*** provides advice on creating consistent measurements and robust evaluation of capacity and safety impact. The ***SAFEPATH-IIT*** tool allows users to quickly understand the potential safety impact of a measure. The ***Empirical research report*** and the ***Road safety analysis report*** summarised how capacity and safety are measured and evaluated, respectively.
To follow an evidence-based approach to qualify project deliverables	SAFEPATH used a robust research methodology to identify and review relevant research, reflecting the six stages of a systematic review (Barends et al. 2014): 1. **Asking**: Turning a problem behaviour or intention into an answerable question. 2. **Acquiring**: Selecting the appropriate source and systematically searching for and retrieving the evidence. 3. **Appraising**: Critically judging the trustworthiness (validity) and relevance of the evidence. 4. **Aggregating**: Weighing and pulling together the evidence. 5. **Applying**: Incorporating the evidence into the decision-making process. 6. **Assessing**: Evaluating the outcome of the decision taken to increase the likelihood of a favourable outcome. The process also incorporated aspects of systems analysis and systems engineering to ensure the research remained applicable to the real-world.

To demonstrate the project outcomes are useable and sustainable for up to 5 years	The SAFEPATH project has worked diligently to provide a strong legacy. Although this is not guaranteed, the following actions provide an excellent base: • Valuable momentum has been generated from stakeholders and end-users to take the project outputs and incorporate them within business-as-usual. • The relevant measures identified to increase highway capacity are applicable to today's highways, but additional information is included in the project outputs about how the impact on capacity and safety may change as future technology developments are realised. • The Practitioners' Guide to Safe Smart Highways is an interactive PDF document that can easily be shared and hosted on other websites. • The SAFEPATH measures database will be maintained by the SAFEPATH consortium until 2027. • The SAFEPATH-IIT tool is Excel-based, which allows it to be shared easily and is generally accessible from a broad range of users.

2.2. Project actions

All project partners were invited to offer their thoughts on what went well and what, by contrast, could have been done differently, in six aspects of the project. This was used to identify lessons learned that can provide future guidance of the challenges faced to others conducting similar or further research. From this feedback, the top lessons learned were identified. These are summarised in Table 2.

Table 2 – The top lessons learned by the SAFEPATH consortium partners.

What went well?	What could be have been better?
✓ Agile approach worked well, allowing faster production of project outputs that provided the opportunity for comment and guidance from the PEB and other stakeholders. ✓ Great project team communication, primarily via email and regular meetings. The project partners agreed to reserve a weekly timeslot for SAFEPATH meetings to reduce time-consuming meeting arrangements. ✓ The project adapted well to personnel change, particularly during WP4000. All project partners acted collaboratively to ensure valuable project experience was not lost. ✓ The WP leaders were always focused on the objectives. ✓ Constructive feedback was provided through multiple channels, including via the PEB, through the Advisory Group, and through dedicated one-to-one engagements. ✓ Sharing the interim reports and Practitioners' Guide at 12 months allowed the project to lay the groundwork for dissemination. ✓ The incorporation of a contingency fund allowed the project to react to new opportunities in agreement with the PEB. ✓ The project consortium maintained a high level of enthusiasm throughout, driven by shared personal experiences and clear communications.	✓ Understanding stakeholder individual goals during initial engagement would have provided better familiarisation with the project and driven earlier knowledge sharing. ✓ Broader NRA input through PEB representatives would have mitigated any criticism that the project is too focused on UK and Netherlands research. ✓ Clearer definitions of some project aspects (e.g. safety modelling) would have minimised misunderstandings. ✓ Seeking agreement on the use of the contingency fund was slow due to a panel approval process. A smaller approval process involving the PEB Chair and the assigned PEB PM would speed up decision making and maintain project momentum. ✓ PEB meeting arrangements were very slow and did place the SAFEPATH project team under pressure to clear diaries. An agreed programme of meetings at the start of the project (dates at minimum) would reduce the preparation burden and ensure greater attendance. ✓ A short timescale (for example, one week) for the delivery of minutes from the PEB meeting should be agreed at inception, to improve the clarity of commitments and expectations. ✓ A face-to-face meeting during project inception may have accelerated relationship developments (note: COVID-19 restrictions were in place). ✓ More use of instant message chat in place of email and some virtual meetings would lead to quicker decision making (note: MS Teams functionality has expanded to make this easier since the start of the project). ✓ Including the end-of-programme conference in the original tender scope would have reduced the additional burden of procurement and organisation at the end of the project.

2.3. Uptake of project outputs and impact analysis

The agile approach of SAFEPATH, the distribution of interim reports (at month 12), and the end-of project dissemination workshops provided the following benefits:

- Stakeholders and potential end-users were able to take advantage of the research gathered, without having to wait until the project completed.
- The PEB and other key stakeholders were able to review the project outputs and provide constructive comments and guidance on the direction of the remaining research activities in the project.
- Sharing the interim project outputs allowed the SAFEPATH team to generate productive engagement with potential end-users, to factor the final project outputs into future business-as-usual applications.

It is therefore possible to determine some level of impact from the project and the potential update of the project outputs

During the dissemination workshops towards the end of the project, the SAFEPATH project team asked the participants to rate their agreement (from strongly disagree to strongly agree) with regards the three main project outputs in two ways:

- Did they think the output seemed useful.
- Did they think their organisation would use the output.

The results from these questions are shown in Table 3. All three outputs were rated highly for usefulness. However, it is interesting to note that most participants went on to rate the likelihood that their organisation would use the output as lower. On reflection, the project partners believe this difference would have been much greater had SAFEPATH not completed the comprehensive engagement and end-user testing activities earlier in the project to generate interest. There exists a strong legacy of stakeholder engagement and good momentum to raise the probability of adoption of the project outputs as the project ends.

Table 3 – Dissemination workshop participant ratings.

SAFEPATH output	'The output is useful' rating	'My organisation would adopt' rating
	(Where 1 = strongly disagree, 3 = neutral, and 5 = strongly agree)	
The Practitioners' Guide	4.6	3.4
SAFEPATH measures database	4.5	3.6
SAFEPATH-IIT	4.5	3.5

Specific comments regarding the three project outputs provides encouragement that uptake will be good. Table 4 provides some examples captured during the dissemination workshops towards the end of the project.

Table 4 – Comments from stakeholders regarding the three main SAFEPATH outputs.

SAFEPATH output	Example comment
The Practitioners' Guide	*'Thank you for a very useful guide and a workshop!'*
SAFEPATH measures database	*'It looks a huge amount of work! Well structured. I need more time to look at it and try it out.'*
SAFEPATH-IIT	*'Seems to give a good first glance of the effect of a measure – but I guess a detailed analysis is necessary anyway as the effect might change by the local infrastructure.'*

All project partners noted the main factor affecting the overall impact of the project was the inherent lack of performance data regarding traffic flow, incident rates, down-time, and other operational factors of the many measures identified.

2.4. Summaries of work packages

2.4.1. WP1000 Project management

Project management procedures, using a proven approach, were successfully put in place to guarantee agreed communication procedures, document distribution methods, resource and time planning, progress reporting, and capturing and managing risk and opportunities. The project coordination role was broad and challenging at times, but above all satisfying coordinating an international team to deliver to an international client.

SAFEPATH Project Management activities included:

- ***Internal progress reporting***: Partners attended monthly virtual project meetings to provide regular opportunity for progress reporting, issue/risk/opportunity escalation, financial reporting, and to agree PEB meeting attendance, all with relevance to work completed and milestones achieved.
- ***PEB progress reporting*** to CEDR, aligned with PEB meetings every 6 months, using information provided by project partners. The coordinator ensured planning for reporting was completed well in advance of meetings, that everyone understood what their role was, timekeeping, and availability to answer any questions. This worked very well and was well supported by all partners.
- A ***project dashboard*** was used to provide itemised progress, illustrated in % complete and a Red-Amber-Green status. This was populated by SAFEPATH work package leaders and used at SAFEPATH internal progress meetings and replicated and consolidated for PEB PM meetings. This reporting mechanism was applauded as it was easy to complete, easy to read, and easy to understand.
- The preparation of a ***quality plan*** to demonstrate to the PEB that processes to manage the technical quality were maintained to a high standard throughout and across partners, using AECOM methods to ISO 9001 and based on the PRINCE® approach. This was delivered after the inception meeting with the PEB and updated as appropriate for all remaining PEB meetings. This set out expectations for draft documents to be internally reviewed by each partner, project reviewed by the Lead Verifier, and issued by the project coordinator on time.

- ***Minutes of meetings*** were produced within two days of all progress meetings to ensure partners were aware of agreed actions. This was further supported by a continuous list of actions that was successfully used to ensure no action was forgotten.
- A ***risk register*** for the project was delivered as part of the submission and provided the basis for risk management throughout the project. It became particularly relevant when there was resourcing issues with TU/e when mitigation measures were implemented successfully and continuously monitored. The same risk register was used for Project team and PEB PM meetings for full visibility.
- A ***project Gantt chart*** was used to illustrate forthcoming milestones and deliverables. It was amended and extended as appropriate, adapting to include the dissemination activities and final programme conference. The same programme was used with the PEB PM for full visibility.
- The project coordinator role extended to ***supporting work package leaders*** in technical and operational tasks to keep deliverables on track. This was particularly evident in supporting TU/e in coaching university staff on NRA operations, expectations, and how to adjust reports and terminology to meet their requirements and be less academic.
- SAFEPATH used a ***quality assurance process*** during the production of deliverables that involved an experienced technical specialist as Lead Verifier to ensure the project was in line with the brief, to challenge the solution, and to drive quality. All reports and key deliverables followed this approach. This ensured greater consistency and reduced the potential number of PEB comments.
- An extensive ***stakeholder management process*** was adopted as part of WP2000, which successfully reached out to many organisations to gather and populate the web-based resources. Acknowledging that greater CEDR NRA member involvement and feedback would have helped further and a sped the approach. This was shown in the need to utilise the project contingency fund to extend the outreach.
- SAFEPATH ***included and declared a risk contingency*** and developed a process to manage and seek PEB agreement for use of risk contingency funds for additional works and enhancements prior to work starting. This was successfully used on two occasions.
- The formation of the ***SAFEPATH Advisory Group*** (AECOM, RHDHV, TU/e, WW, ANAS, ika) provided a strategic steer, guidance, and support to the project team throughout the duration of the project. Meetings aligned with key project activities at the start, stakeholder workshops, and key milestones.

The project coordinator ensured the SAFEPATH milestones and deliverables we appropriate. The programme, planning and quality of delivery, described above really made a difference to the project team. During the project, the SAFEPATH team revised delivery dates so that the PEB was not overwhelmed with reports to review simultaneously. This was documented, agreed, and appreciated by the PEB.

2.4.2. WP2000 Systems analysis

In recognition that the relationship between safety and capacity is complex, with many levels of interactions, a systems analysis approach was used to understand the system of how capacity and safety impact each other. Systems analysis provides a way to analyse the effect of different

means (or in the case of this project, measures) to improve capacity and safety. One key limitation is that systems analysis does not model a complete system. Instead, it focuses on the most important factors that are critical to understanding the system.

The SAFEPATH project used a systems analysis approach to examine the problem of increasing highway capacity. The process involved the development of various models known as means-ends, objective tree, and causal relations. A systematic approach involving literature reviews, interviews, and workshops with experts was followed to develop and refine various models.

These models allowed the creation of a systems diagram for highway capacity and road safety that serves as a tool to understand and assess the different means for increasing highway capacity and to relate them with measurable criteria. This would help NRAs in making informed decisions regarding selecting appropriate measures to safely increase highway capacity and establishes a firm foundation on which a good practice guide for highway capacity measures can be created.

An example of the output of this analysis is provided in Figure 4. This shows how a user may use certain criteria to measure the impact of a measure on capacity or safety of the highway. Each of these criteria is influenced by many factors, sometimes positively and sometimes negatively.

This work package produced an interim technical report titled the ***Problem and systems analysis.***

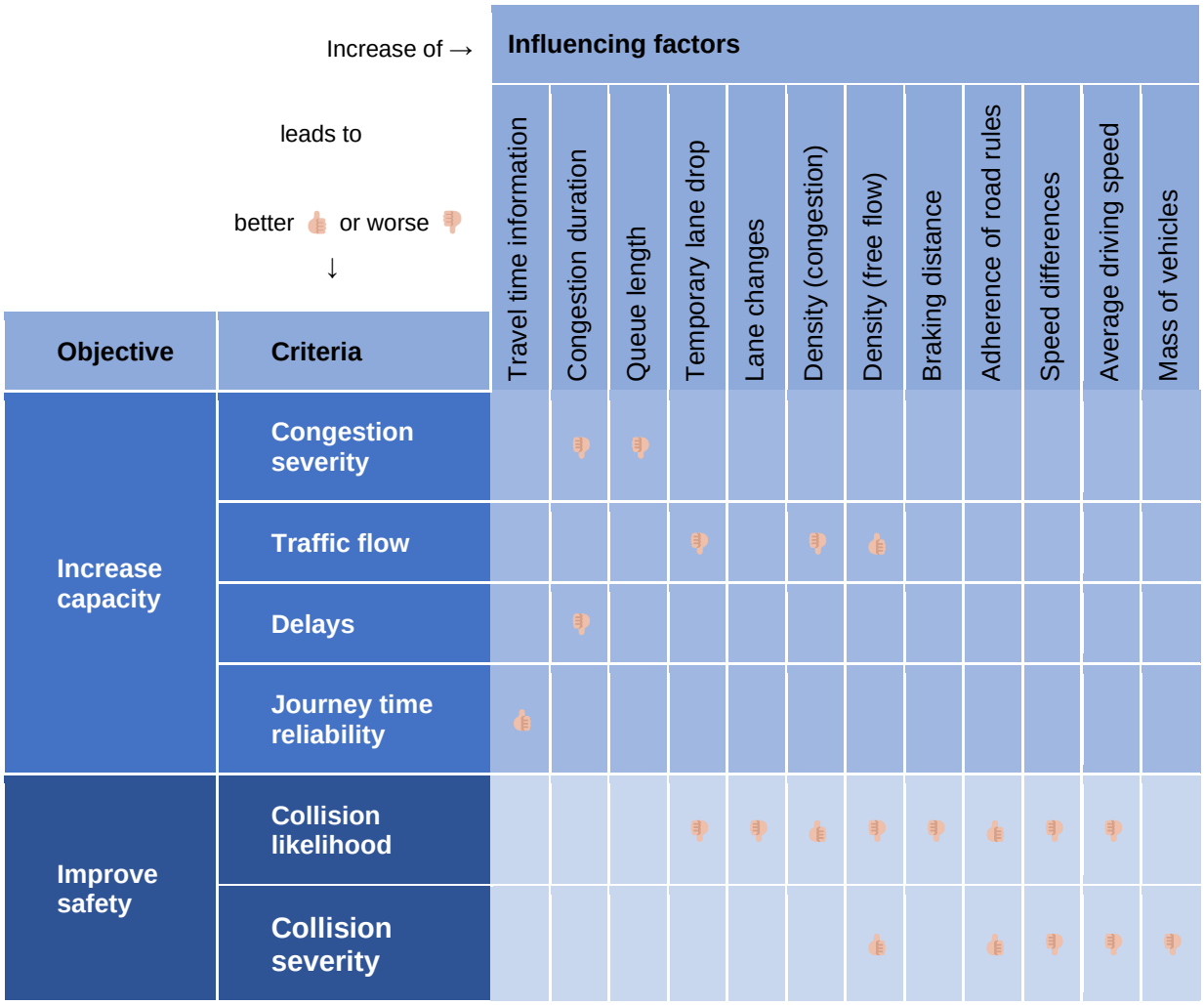

Figure 4 – SAFEPATH objectives and influencing factors.

2.4.3. WP3000 Empirical research

This work packages focused on the systematic identification and evaluation of research or reports on measures to increase capacity on highways, leading to the construction of a database of measures. The database includes an assessment of the measure's impact (where known), examples of implementation, and other relevant environmental, financial, and societal factors.

A literature search was conducted, with search terms taken from previous work performed in WP2000. Key repositories of literature that were searched included Google Scholar, Science Direct, Directory of Open Access Journals, SafetyLit, PsychInfo, Scopus, Social Science Citations Index, the Road Safety Observatory, and previous CEDR publications.

A **Stakeholder engagement plan and tracker** were developed. This enabled the collection of further information on capacity-increasing measures that had already been implemented by some of the stakeholders.

Forty-six measures were identified in total. They fell into three types:

- Those which increase basic capacity – for example, dynamic assignment of road space.
- Those which increase compliance – for example speed enforcement.
- Those which maximise up-time – for example, efficient incident management.

A website was created (accessible at https://project-safepath.azurewebsites.net/), which includes a searchable database of all the measures and places of implementation. The measures page of the website database is shown in Figure 5.

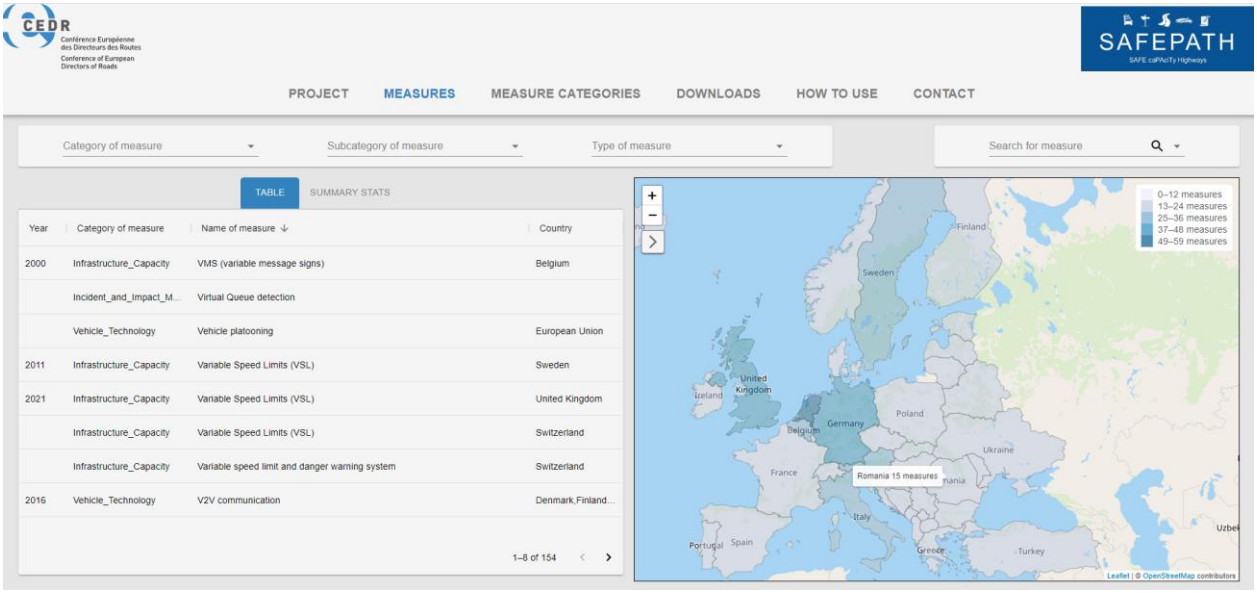

Figure 5 – Web page of the SAFEPATH database website.

This work package identified several gaps in knowledge:

- The robust quantification of the success or otherwise of many of the measures was lacking.

- There is very little reliable information on the transferability of measures – for instance, whether the success (or failure) in one country or region be used to predict results in another.
- Many assessments of the impact on capacity do not provide evidence on the likelihood or otherwise of induced demand.

2.4.4. WP4000 Road safety analysis

The objective of this work package was to investigate the safety impact of existing and evolving highway capacity measures. The findings from WP4000 provided a better understanding and insight into the impact on highway safety of measures NRAs may wish to implement to increase capacity.

The most relevant KPIs for road safety were identified as collision likelihood and collision severity, in line with the findings WP2000. In this work package, two approaches to analyse the safety impact of capacity measures were used. The first approach focused on finding evidence on each capacity measure's safety impact using existing studies in the literature. In the second approach, the system analysis from WP2000 was performed to create a model that was used to estimate the potential safety impact of implementing a specific capacity measure. The safety impact estimation model focuses on the most important factors that are critical to understanding the system.

To collect evidence on each capacity solution's safety impact and lessons learned from similar road capacity projects, this work package began with reports such as those from CEDR, ESTC, PIARC, and AASHTO, which have already published analysis findings and recommendations on highway safety. A literature review was conducted on those scientific studies that emphasise pre-post analysis and surveys from NRAs.

Several measures, such as ITS and C-ITS services, are evolving, so their results are mostly derived from simulation data or controlled experiments instead of captured real-world data. Therefore, the findings in WP2000 contain evidence both from real-time analysis and simulation analysis. Providing evidence of both types is valuable for understanding capacity measures' safety performance level and the likely impacts of measures yet to be deployed at scale.

This work package proved more complex than initially expected, and additional labour resource was deployed.

2.4.5. WP5000 The Practitioners' Guide to Safe Smart Highways

This work package consolidated the research performed in earlier work packages to produce an accessible guide aimed at anyone involved in the planning, designing, or implementation of measures to increase capacity on highways. To reflect the desire of most NRAs, the Practitioners' Guide focuses primarily on helping make the most of the physical infrastructure that is already in place.

The guide can be consulted at any stage of the infrastructure life cycle, but is designed for use in decision making, policy development, and during the selection of appropriate measures to increase highway capacity. The guide also aims to highlight the future operational impact of new technologies such as automated and connected vehicles on capacity measures.

The guide is aimed at NRAs managing highways in Europe (strategic or major roads). However, it includes evidence from highways outside of Europe where comparison is appropriate. It presents measures to increase highway capacity that are well established or have a good evidence base.

It is produced as an interactive PDF. This allows it to be shared widely and easily. In common with current trends, the document is designed to be accessed primarily via a digital medium – thus it is produced as a landscape document and includes links and hyperlinks to ease navigation.

It takes advantage of the availability of the SAFEPATH measures database website (accessible at https://project-safepath.azurewebsites.net), by providing a relatively high-level overview of measures that allow the user to quickly determine whether it is applicable to their situation. Should the user require more detailed information, they are invited to delve deeper by using the information provided on the website.

To help compare the various measures they have been divided into three categories:

Increase basic capacity	**Increase up-time**	**Increase compliance**
Measures that increase the theoretic maximum capacity of a highway. For example, utilising the hard shoulder to create more lane running area.	Measures that increase the time during which the basic capacity is available. For example, resolving incidents faster to recover capacity.	Measures to improve road user compliance to achieve the basic capacity. For example, using speed enforcement to reduce flow breakdowns.

A typical page summarising a measure to increase capacity is shown in Figure 6.

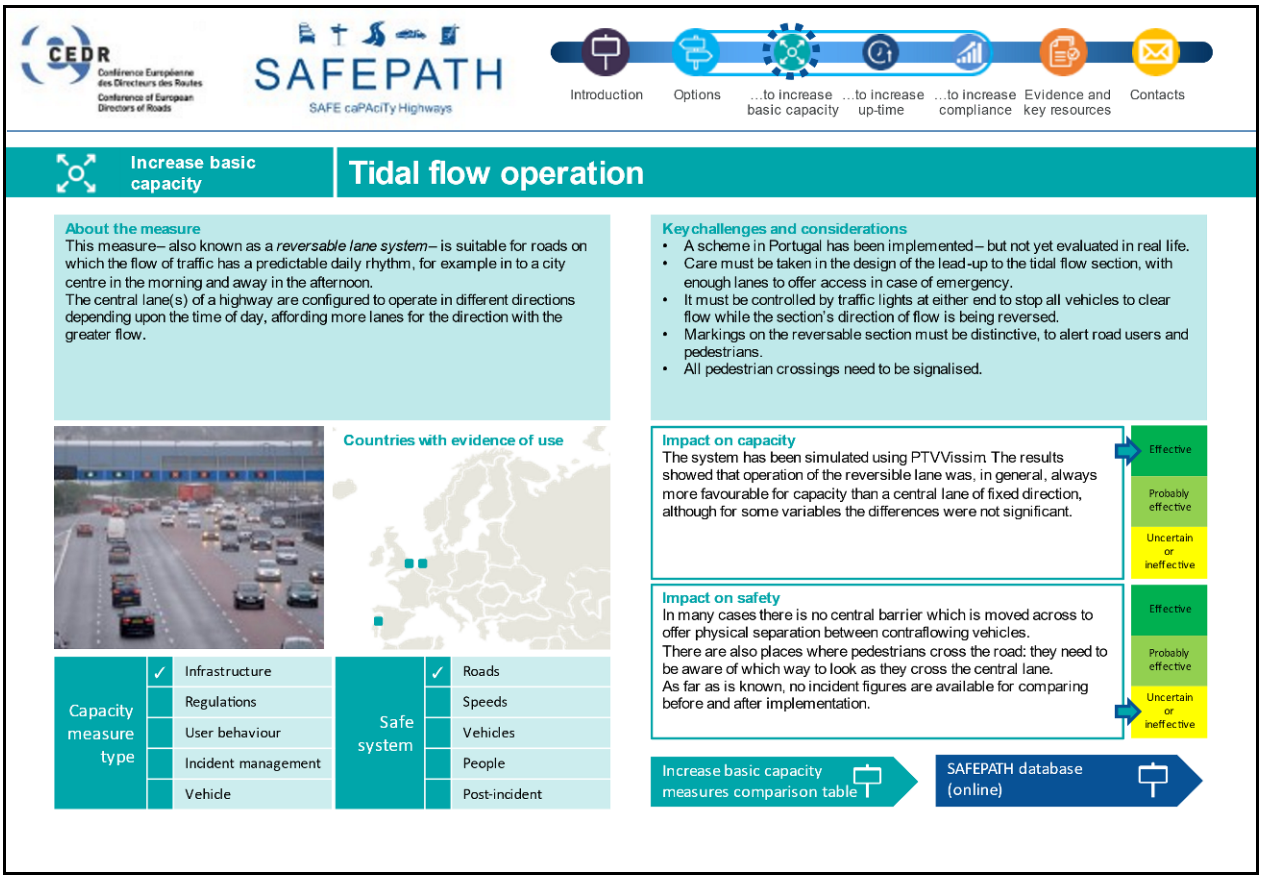

Figure 6 – An example page from *The Practitioners' Guide to Safe Smart Highways*.

2.4.6. WP6000 Final report

This work package involved the production of this report. This focused primarily on the empirical data discovered and research carried out, recommended measures to increase the capacity of highways, and summarise developments that may help to fill any gaps in knowledge. It includes reference to the dissemination work carried out, accounting for its success.

Although the output of this work package relies on the completion of all other work packages, the activities to capture information for the final report began shortly after project inception and continued throughout. For instance, to ensure all lessons learnt and gaps in knowledge where recorded as they were discovered.

Specific tasks carried out as part of this work package included:

- Reviewing actions completed against those described in the original proposal and identifying lessons learned. This allows onward guidance to others conducting further or complementary research on the challenges faced, the approach adopted and its relative success.
- A review of the uptake and use of interim reports and deliverables – to understand how the agile approach delivered valid information into the public domain.
- Compiling summaries from work packages and capturing the actual methodology used.
- Conducting impact analysis – reflecting on feedback from the interim and final reports and ongoing dissemination activities that demonstrate the initial value of the research to CEDR.
- Producing this final report.

2.4.7. WP7000 Dissemination

The SAFEPATH consortium has been conscious from the start of the project that the project outputs are of little practical purpose if the relevant people and institutions remain unaware of them. The project plan included extensive dissemination activities starting at month 18 – providing 6 months of effort to provide a strong legacy for the project. In actuality, dissemination activities started even earlier, with a prominent position at the ITS European Congress in Toulouse at month 12.

Dissemination occurred first and foremost among the SAFEPATH stakeholders, including CEDR PEB members and NRAs. The future publication of the SAFEPATH outputs was widely advertised during any interaction, to allow potential end-users to factor the use of the outputs into their future plans.

SAFEPATH project members also presented at and attended several high-profile events. This included:

- Presenting a paper at the ITS European Congress in Toulouse, in May 2022
- Hosting a Special Interest Session at the ITS European Congress in Toulouse, in May 2022
- Presenting at the UK National Road Safety Conference in Harrogate, in November 2022
- Presenting a paper at the Transport Research Area in Lisbon, in November 2022
- Submission for a Special Interest Session at the ITS European Congress in Lisbon, scheduled for May 2023

Throughout the project, the SAFEPATH team have hosted virtual workshops and meetings with stakeholders and potential end-users. Attracting attendees to initial meetings proved more difficult than anticipated, but by using the project's agile approach and utilising the risk contingency, additional effort was deployed to increase engagement. By the end of the project, the SAFEPATH dissemination workshops realised the benefits of this extra effort as each meeting involved approximately 30 attendees from various NRAs.

2.5. How the research is applicable now and in future

Implementation of new projects to increase capacity are likely to begin and continue after the official close of the SAFEPATH project. However, further CEDR projects are likely to be conducted in related fields – for instance, enhancing road safety and/or capacity. When these further projects in turn are written up and disseminated, mention can be included of the findings of SAFEPATH.

2.6. Recommended future work

2.6.1. Options for future projects

Throughout the SAFEPATH project, WP6000 monitored the other work packages for opportunities for further work. The following provides a summary of these observations.

- ***Additions to SAFEPATH measures dataset****:* Various end-users reported the desire to be able to add content to the database as it becomes available. This reflects the good momentum generated through SAFEPATH regarding knowledge sharing between end-users.
- ***Performance data for potential measures***: There are many measures that show strong potential to increase capacity on highways, but the supporting evidence is either weak or purely theoretical. This is particularly evidence for measures targeting road user compliance (such as behaviour-based interventions). More data on the performance of the various measures is needed – such as pre- and post-analyse of measure implementation.
- ***Financial evaluation****:* Participants at the dissemination workshops highlighted how cost feasibility information would be of significant use for end-users of the Practitioners' Guide. Although it is acknowledged that detailed financial evaluation of the implementation of a measure for all countries may not be a suitable future project scope, it would be reasonable to perform research to capture information on average costs, maximum or minimum expected costs, or lists of financial considerations. In addition, this work should consider public acceptance of measures and economic assessments such as willingness to pay or willingness to accept.
- ***Perception of safety****:* This is viewed as increasingly important for the widespread adoption of measures, particularly in areas where the level of road safety is already high. There is an inherent link between the feeling of space and the feeling of safety, which can be impacted by implementing measures to utilise more of the space. Methodologies to assess perception of safety are available and could be developed further to establish guidance.
- ***Research synthesis for ADAS issues***: There is a growing volume of reports regarding the impact and challenges of advanced driver assistance systems (for instance, sign reading errors). A synthesis of these reports would be valuable to NRAs.

2.6.2. Further dissemination of the SAFEPATH project outputs

As the project officially closes, the momentum generated by the SAFEPATH stakeholder engagement should be exploited to maximise dissemination. Project partners will continue to use their professional connections to share the knowledge, but NRA members are also encouraged to utilise their own influence and presence within partner organisations to disseminate the project outputs. This should include through:

- ***The ITS industry***, for example National ITS groups, such as ITS-UK, Connekt, ATEC, along with organisations in the automotive industry and service providers.

- ***Academia***: the research provides an up-to-date view and analysis of safe measures to increase capacity, including some fringe aspects such as the influence of human factors and the environment that affects the success of any safe smart solution.
- ***Schools and STEM***: Solutions employed now and in future will have a direct impact on the young, as future road users and as possible influencers on the development of future technologies. SAFEPATH material can be used to support Science, Engineering, Technology and Mathematics (STEM) and upskilling activities for schools and colleges.

3. Conclusions

The SAFEPATH consortium, comprising AECOM, Royal HaskoningDHV, Eindhoven University of Technology, and White Willow Consulting, completed research to deliver information on good practice on increasing capacity and whilst maintain or improving safety through smart safe highways. The project formed part of the CEDR 2019 (2) Research call. This project arose from the need to increase capacity on European highways without compromising safety and without physically widening highways.

The project was organised into seven work packages: WP1000 Project management; WP2000 Systems analysis; WP3000 Empirical research; WP4000 Road safety analysis; WP5000 The Practitioners' Guide; WP6000 Final reporting, and WP7000 Dissemination of results.

A systems analysis was carried out, from which a causal relations diagram was created, depicting all the primary components of the system and their relationships. A literature search, together with stakeholder engagement including outreach to NRAs throughout Europe, was undertaken to discover what measures had been put in place to safely increase highway capacity, and with what results.

Information from this work fed into the Practitioners' Guide to Safe Smart Highways. The Guide takes the form of a PDF, supported by an online SAFEPATH measures database, and an Excel-based safety assessment tool called SAFEPATH-IIT, which enables NRAs to identify and assess the effectiveness of measures for safely increasing highway capacity. The appearances of these project outputs are shown in Figure 7. This part of the work was carried out in two phases: Phase 1 identified quick wins among the various measures used to safely increase capacity, which were then published in interim versions of the Guide and project reports to participating stakeholders. Stakeholder feedback then enabled refinement of the Guide, database, and SAFEPATH-IIT. Stakeholders were consulted over their level of satisfaction with the work, which proved to be high.

Figure 7 – The three primary outputs from the SAFEPATH project: *The Practitioners' Guide to Safe Smart Highways*; The *SAFEPATH measures database website*; and the *SAFEPATH-IIT* road safety impact indicator tool.

The initial involvement of stakeholders helped in identifying routes of dissemination. In addition to already-established channels these included conferences, the ITS community, project dissemination workshops, academia, and STEM activities.

The project concentrated on measures that have already been implemented – either in Europe or elsewhere in the world – rather than attempting to model or evaluate measures that have not yet been put into practice. This was done to provide NRAs with evidence-based options that could immediately be used. Measures chosen concentrated on those which fall within NRAs'

remits, and so concentrated upon infrastructure and legislative measures rather than, for example, those involving in-vehicle technology.

Lessons learned in the management of the project included the need for swift access to the contingency fund to deal with unexpected unavailability of staff, and handling the difference in outlook, including research and report-writing style, between academic and commercial participants – particularly in work which turned out to be more complex than initially expected.

Lessons learned in project content included the need for more data on the actual performance of the identified capacity-enhancing measures, including in the short term, in the longer term, and in terms of road user safety. Very little information was found that might help in assessing the transferability of a measure from one location to another – for example, on the effects of factors such as economics, climate, and driving culture.

SAFEPATH complements other CEDR projects such as SHADAR (stopped vehicle detection), and ultimately, will help the flow of goods and services throughout the territory and thus contribute to aims of the European Union[4]: which include enhancing economic, social and territorial cohesion and solidarity among EU countries, combating social exclusion and discrimination, and protecting and improving the quality of the environment.

[4] https://european-union.europa.eu/principles-countries-history/principles-and-values/aims-and-values_en