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Final Programme Report: CEDR Call 2021 Remote Condition Monitoring of Physical Road Assets

INFRACOMS

Innovative and Future-proof Road Asset Condition Monitoring Systems

April 2025

CEDR Call 2021 Remote Condition Monitoring of Physical Road Assets Final Programme Report

CEDR Contractor Report 2025-02

by

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1. Executive Summary

The aim of this programme has been to undertake research into new technologies on the remote monitoring and inspection of physical road assets and provide advice on implementing new techniques as business practice. The programme has aimed to address the problem that many new technologies are being developed for road and bridge condition assessment, but NRAs do not have the means or capacity to efficiently evaluate and implement these technologies.

The programme has been delivered via a single project – INFRACOMS (Innovative and future proof road asset condition monitoring systems). This report summarises the main tasks, outputs and lessons learned from the project, and provides information for CEDR that may be useful for designing and implementing future projects, to understand how to embed the results and how NRAs might engage in and use the outputs of the project.

An explanation of the work undertaken is presented Chapter 2, which describes all seven of the INFRACOMS Work Packages (WP). In summary: Work Packages 0 and 6 provided project management and dissemination tasks; WP1 explored current practice in understanding asset condition, the future needs and concluded with a knowledge/technology gap analysis; WP2 covers appraisal of condition monitoring new technologies, including a methodology evaluating their potential, as well as developing a tool developed for appraising technologies in an online Wilki called Confluence; WP3 develops a technology scoring system, which is also incorporated into Confluence; WP4 presented case studies of the new technologies (also added to Confluence); WP5 developed a self-assessment toolkit for NRAs to review their capacity to innovate, and provided frameworks for NRAs to develop an organisational roadmap for their own capacity development, and technological roadmaps for particular technologies they want to implement. Finally, WP6 presents proposals for future demonstration projects that could practically assess potential technologies on the network.

Following the presentation of the project, Chapter 3 presents three options for the way forward with regard to wider implementation of the INFRACOMS outputs. These options are distinct, but are not mutually exclusive and different elements can be undertaken as per the needs of the NRA.

- Option 1 would implement the INFRACOMS methodology within one or more NRAs. It would allow individual NRAs to progress with the self-assessment and organisational development and adopt the methodology internally at their own pace. If this is successful in enough NRAs, or shows enough promise, it would be possible to move on to option 2 at any stage.
- Option 2 would fully implement the INFRACOMS methodology across NRAs. This would build a collaborative culture between NRAs to help NRAs evaluate and make informed decisions on whether to implement new technologies, and to develop robust implementation plans. This option fully embraces all of the tools that were developed under INFRACOMS, leveraging the full benefits from sharing information between NRAs.
- Option 3 would undertake no further development of the tools in INFRACOMS, but would keep the Confluence platform active, through free subscriptions. This approach would allow individual NRAs to support and advance the solutions independently, incurring minimal involvement and cost. However, it would offer limited benefits due to a much lower level of information sharing.

Chapter 4 discusses these options in the context of sustainable transport and the three pillars of economical, societal and environmental development. The options for ways forward are focused on the development of an innovation culture and implementing new technologies as effectively as possible within NRAs, but the pillars are more relevant to individual technologies, so a scoring system was not possible. However, the benefits of each option were compared in the context of how the NRAs could implement the INFRACOMS tools into the future. Option 2 was found to have the

most benefits due to its comprehensive approach, promoting both innovation and practical implementation within the NRAs, while also fostering collaboration and information sharing.

Active adoption of the methodology and tools beyond the project is going to take time and resources from NRAs, and would benefit from some input from CEDR. The investment already made in the project is significant and should be protected by maintaining the Confluence tool and fostering a culture of innovation and sharing among NRAs. The consortium has agreed to continue support to the tool until October 2024. Chapter 4 discusses options for continuation beyond October.

Chapter 5 describes the INFRACOMS Final Event, which was held in Oslo on 23rd and 24th October 2024. The Final Event was hosted by the Norwegian Public Roads Administration (NPRA) and CEDR. It included a summary of all work done on the project, and offered the opportunity to explore options for going forward in detail.

Chapter 6 presents the conclusions of the project, including identification of the likely benefits under each of the technical options going forward.

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2. Definition of the Issue (problem)

This report is not a summary of the INFRACOMS project per se, but it does highlight the main activities and learnings from the past two years. It also describes the tools produced by the project and how they were developed, whilst also demonstrating how they can be used by CEDR members in the future.

The report is arranged as follows:

Section 1: The Executive Summary.

Section 2: Definition of the issue: This section defines the problem that was addressed by the project, the purpose of the project and its scope.

Section 3: Possible ways forward: This section discusses three options for a way forward for the INFRACOMS outputs. Hence this section presents the strategic pathways that CEDR members could adopt to implement the outcomes of INFRACOMS to foster innovation and effectively implement new technologies.

Section 4: Comparison of possible ways forward: This section compares the options presented in the previous section. The pros and cons of each way forward are assessed and compared in respect of the three pillars of sustainability: The societal, economic and environmental aspects.

Section 5: Conclusion: This section presents the conclusions in relation to the objectives of the work and outlines the main points, presenting logical outcomes of the project.

2.1 Problem:

Rapid innovative technological changes are creating opportunities as well as challenges for road authorities and asset managers. There has been a surge in the development of technological solutions and systems, some claiming to solve the problems that asset owners face. The availability of these alternative solutions allows asset owners to start thinking differently. However, transitioning to new solutions poses a substantial challenge, in that it is difficult for asset owners to evaluate the best possible technological options that will add value to their Asset Management. However, to both move forward and keep up with the future change, a continuous evaluation process needs to be embedded as business practice.

2.2 Purpose:

The aim of this programme has been to undertake research into new technologies for the remote monitoring and inspection of physical road assets, and to provide advice on implementing new techniques as business practice. This report provides information for CEDR that can be useful for designing and implementing future projects, in terms of uptake and embedment of results and how NRAs can engage in and use the outputs of the project.

2.3 Scope:

The scope of this report includes:

- A reminder of the main issues and the problem that motivated this project, as outlined in the DORN. The outputs from projects undertaken under five previous CEDR calls were relevant to this call, two regarding asset management in 2010 and 2014, two on BIM in 2015 and

2018 and the most recent in 2020 on CAD for smart safe roads. These provided useful background to the project, although it is recognised that this is a rapidly developing sector, and the problems are unique to the current operating environment.

- A summary of the methodology used to implement the project including the work undertaken over the past 24 months, the output produced, and any tools developed. Although this information is not core to the outcome of the report, it is important for the reader to understand how tools and guidance developed.
- A summary of how the project has been disseminated, including the website, promotional material, any papers produced, and presentations made at international conferences.
- Potential ways forward for the NRAs involved in the PEB, and more generally for all NRAs in CEDR. Three options are presented, including 'Do Nothing', a scenario where collaboration is grown gradually via individual NRAs, and a comprehensive scenario that supports NRAs and allows them to interact.
- A comparison of the potential ways forward, set in the context of the three pillars of sustainability: Societal, economic, and environmental.
- Conclusions that relate to the objectives of the work, and which outline the main points and outcomes.

2.4 Methodology:

The INFRACOMS project was divided into five main work packages, with two support packages, one for project management and one for dissemination. Each work package was designed to help address the aim of the project as stated in the DORN, to "undertake research into current best practice on the remote monitoring and inspection of physical road assets and provide advice on implementing new and emerging technologies as business practice." Figure 1 shows a diagram of the INFRACOMS Work Packages and how they interlinked.

Each INFRACOMS partner organisation was assigned a level of effort to achieve the outputs, according to their particular speciality. From this, a Gantt chart was produced to show the timings of inputs and outputs throughout the two years of the project. Figure 2 shows an organizational chart that illustrates how responsibilities were assigned to project partners.

The following sections provide further details on the work undertaken in each work package.

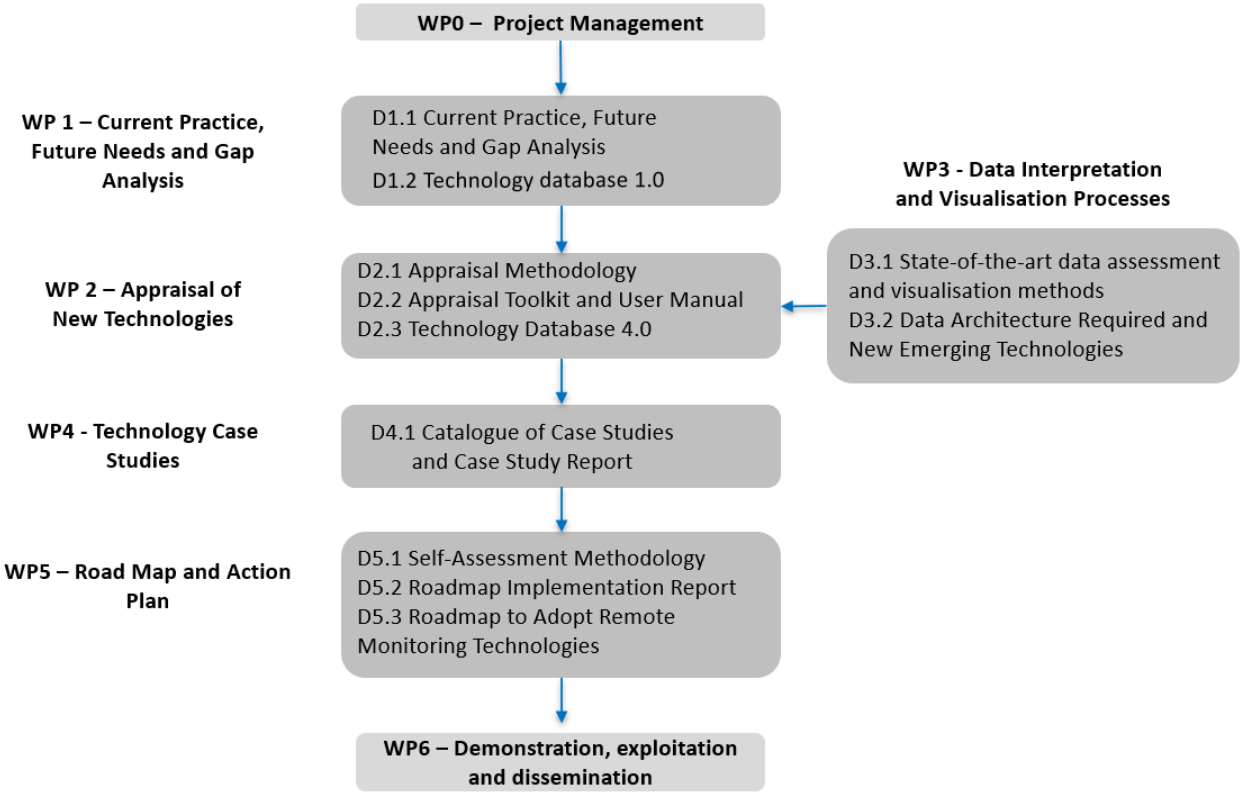


Figure 1: Work Packages for INFRACOMS.

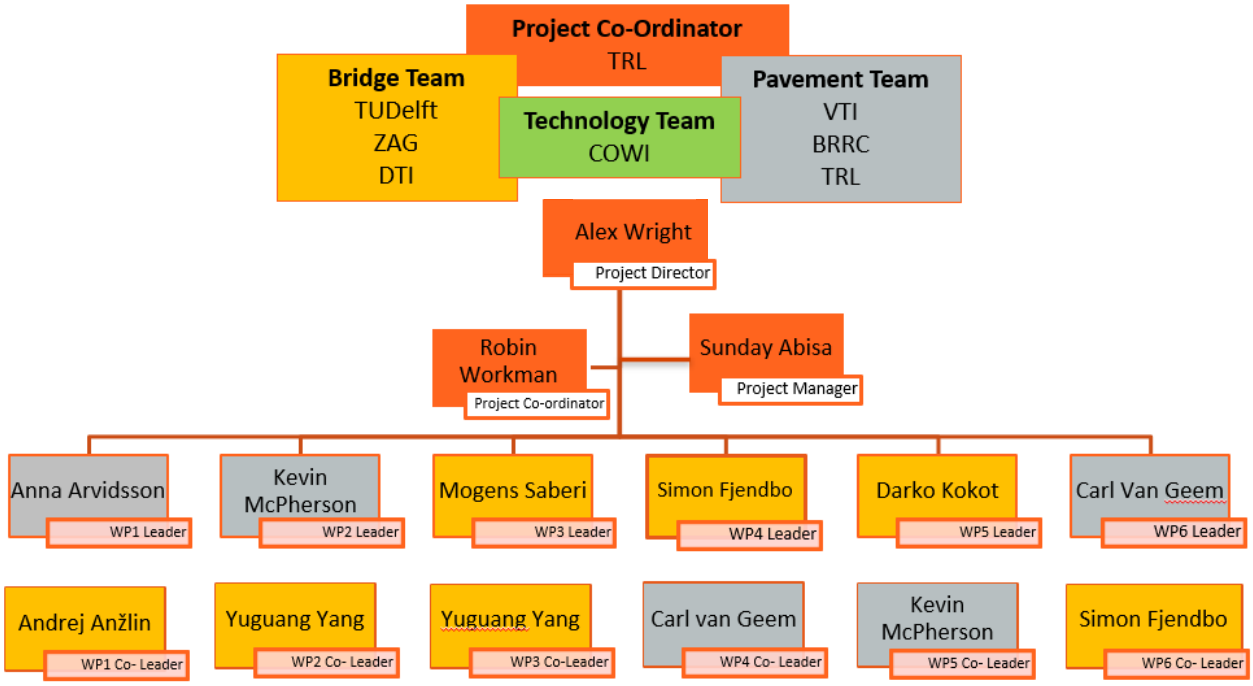


Figure 2: Organisation chart of the project partners.

2.4.1 Work Package 0 (WP0)

Project Management

Work Package 0 was structured around overall project management, strategic leadership and technical assurance. This WP provided the overall direction of the research, and initiated/managed collaboration with the client and with technology suppliers. Existing relationships between consortium members and NRAs were also exploited. WP0 included the project inception meeting, as well as regular internal consortium meetings and PEB progress meetings. The PEB committee was relied upon to provide advice also to help disseminate the progress and outcomes to the wider PEB and other NRAs.

2.4.2 Work Package 1 (WP1)

Current Practice, Future Needs and Gap Analysis

This work package liaised with NRAs to identify good practice in data collection and standards, and also to identify and understand the gaps in relation to what is required for asset management.

WP1 gathered information via a literature review of current practice and use this to provide the foundations for surveys which were sent to NRAs and the technology providers. This included questions on what gaps stakeholders see in their data and in their impementation of new technologies, and their current priorities and future needs. For example, in terms of data collection the following questions were asked:

- What specific sets of data could enhance decision-making processes?
- What requirements are there for inspections that may be carried out more safely, or with less disruption to traffic, or in a more cost-effective way?
- What are the requirements/views on the use new technologies to complement current data collection methods, and to make more efficient maintenance investments in the future?

In parallel with the NRA survey, a separate set of questions was sent to technology providers who had registered an interest in the INFRACOMS project.

An analysis of the literature review and the outcomes of the consultation were used to identify current practice at NRAs in relation to asset data collection, considering the methods, techniques, intervals and use. This determined the current state of affairs within NRAs, what practices are currently carried out, what data are collected and how these are used.

The survey answers and literature review were combined with a review of new and emerging technologies. This enabled the project team to suggest which gaps and information needs existed.

This resulted in the following Deliverables:

- Current Practice, Future Needs and Gap Analysis report (D1.1)
- A database (Technology Database 1.0) of the new technologies that were discovered (later added to the Confluence Wiki tool).

2.4.3 Work Package 2 (WP2)

Technology Appraisal

This work package built on WP1 to develop a methodology to appraise the potential of new technologies. Several commonly-used appraisal methodologies were reviewed for their ability to evaluate the effectiveness, suitability and potential impact of new technologies for an organisation, including Technology Readiness Levels (TRLs), Cost Benefit Analysis (CBA), Life Cycle Cost Analysis (LCCA), Risk Assessment, and Multi-Criteria Decision Analysis (MCDA). Elements of these

were then included in the INFRACOMS Appraisal Methodology, building-in feedback from a workshop held with NRAs.

The INFRACOMS Appraisal Methodology is based on the concept of a "technology use case" for an NRA. This focusses the appraisal on assessing the potential benefits of the technology under consideration when applied in a specific way on the network. The methodology includes three core processes, Pre-Evaluation, Evaluation and a Case Study, The level of assessment will depend on the maturity of the technology. Therefore a developing and untested technology may only be suitable for pre-appraisal, whereas a mature product that is commercially available could be appraised over all three levels. The appraisal process also includes processes for NRAs to define their strategic and technical priorities so that the appraisal can be tailored to address their individual requirements. The technology appraisal process is shown in Figure 3.

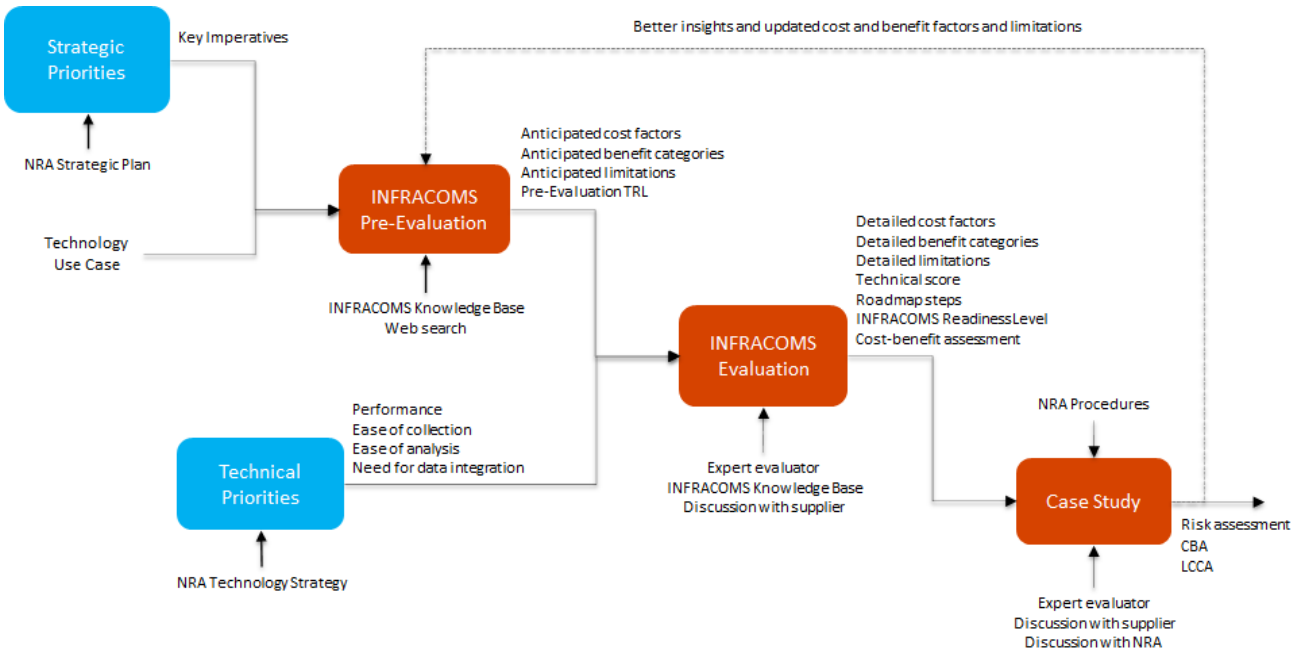


Figure 3: Technology Appraisal Process.

- **Pre-evaluation.** Pre-evaluation provides a high-level description of the technology, analysis of the anticipated cost factors, benefits and limitations of the technology use case. This can be accomplished quite quickly (with perhaps 2 – 3 hours of inputs) based on research from the INFRACOMS knowledge base and/or web searches. Completion a pre-evaluation requires general knowledge of technologies and their applications, and an understanding of potential NRA applications.
- **Evaluation.** Evaluation carries out a more in-depth appraisal. It builds on an assumption that the proposed technology is to be applied in a "use case" associated with an existing decision-making process in the NRA – i.e. that this new technology is being evaluated as a potential replacement for (or improvement to) the technology or data that currently supports this decision-making process. It directly associates the technology with specific business/operational activities of the NRA, to focus on the objectivity and value of the appraisal process.
- **Case study.** The case study process is covered under WP4.

Implementation within the Confluence Toolkit

The appraisal methodology process was used to develop an Appraisal Toolkit. Initially INFRACOMS had proposed this be contained within an Excel spreadsheet. However, it became clear that a Wiki type online platform would be more appropriate in terms of sustainability and sharing information between NRAs - which would be the main benefit of the project. A tool was therefore designed in the Confluence platform, which is well established and widely available and has low licence costs. Ultimately the database of new technologies identified in WP1, the appraisal toolkit and case studies were incorporated into Confluence.

The INFRACOMS toolkit contained within Confluence can be seen in Figure 4. To develop toolkit the consortium procured licences for the consortium and selected PEB members. The project then undertook work to develop, populate and refine the tools. At the completion of the INFRACOMS project the Confluence tool was still under the management of TRL (consortium lead member), with 67 licences provided, including those in the Consortium (15). The future use of the tool is explored further in Chapter 4.

WP2 resulted in the following Deliverables:

- Technology Appraisal Methodology report (D2.1)
- Appraisal Toolkit User Manual (D2.2)

In addition WP2 delivered the first version of the Confluence toolkit, that was then refined in the further WP.

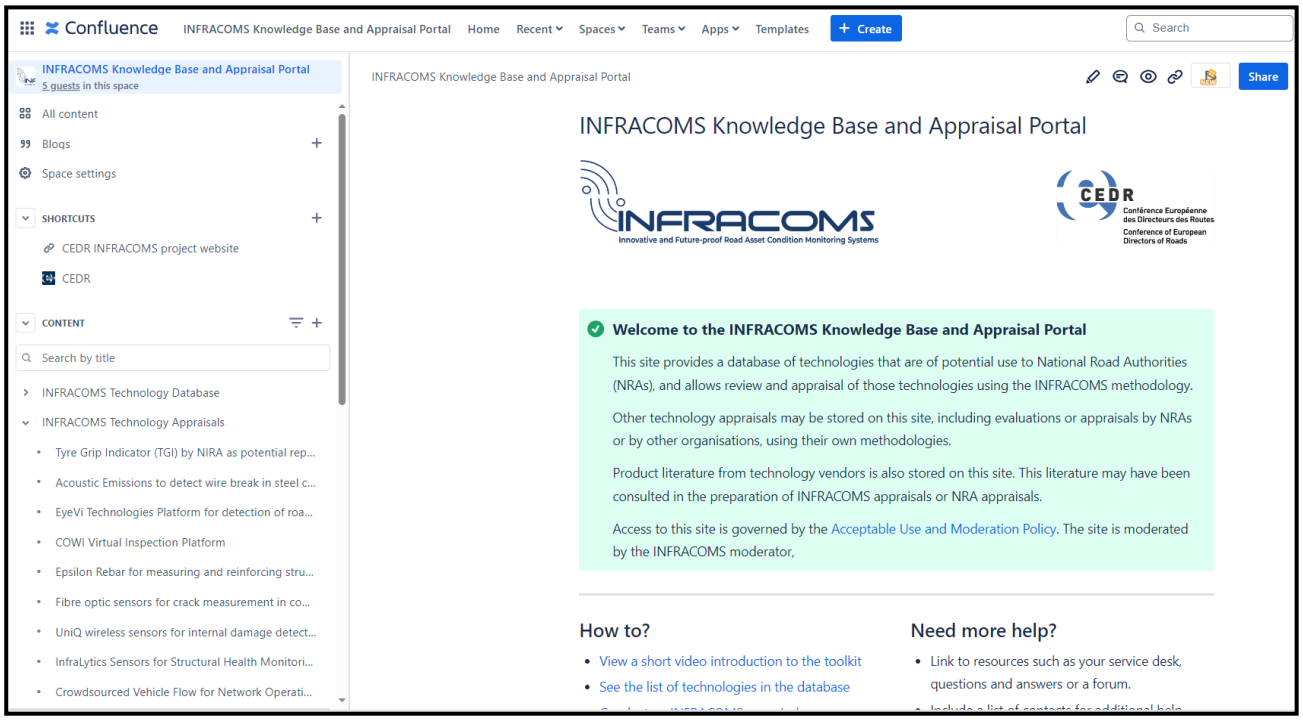


Figure 4: INFRACOMS Confluence toolkit.

2.4.4 Work Package 3 (WP3)

Technology Appraisal and Data Visualisation

A key objective of WP3 was to develop a scoring system to appraise technologies applied in specific use cases. The intention of the scoring system was that individual NRA's then can compare different technologies that close the same gap. Key areas to be scored were initially determined by the INFRACOMS group. These areas were further refined through discussions and interviews with various NRAs. For the development of a scoring system for the "data architecture" area, information was sought from NRAs on existing data architectures. The appraisal method was incorporated into the Confluence tool.

In addition to the development of a scoring system WP3 described state of the art technologies for data analysis and visualisation. This information was mainly collected though networks in the industry, universities, and internet searches. WP3 provide the following Deliverables:

- State-of-the-art data assessment and visualisation methods (D3.1)
- Data architecture required for new and emerging technologies (D3.2)

To provide context to the concept of data architecture D3.2 has described a generic data architecture, which encompasses most of the architectures that would currently be used by NRAs (Figure 5). This generic data architecture includes the following segments:

- Data collection (inclusive of Metadata, Technology, and Data Source)
- Data ingestion and storage (inclusive of Data Ingestion, Data Ontology, and Data Storage)
- Data consumption (inclusive of Data Analysis, Data Visualisation and Decision Making).

The experience gained reviewing NRA data architectures was applied to develop an approach in the appraisal toolkit to appraise the ability to integrate a proposed new data type into an existing data architecture. The appraisal is based on scoring the anticipated complexity of implementing the new data within each part of the data architecture pipeline. This is based around a scoring sheet which covers the following aspects:

- Data collection (including Data source type and Data fidelity)
- Data ingestion and storage (including ingestion frequency, automation, and Data organisation).

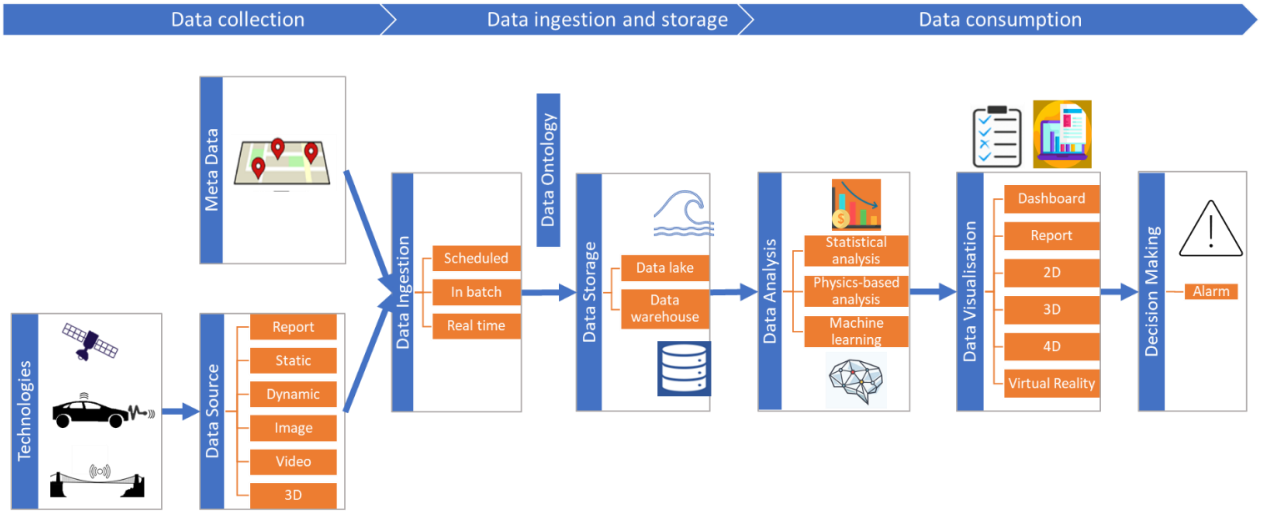


Figure 5 The generic INFRACOMS data architecture model.

2.4.5 Work Package 4 (WP4)

Case Studies

WP4 developed a catalogue of technology case studies, drawing on several sources (such as the internet, (N)RAs, and technology providers). Whilst initial basic information was obtained about selected technologies from previous work packages, detailed and case-specific information about technologies was obtained via direct engagement with technology providers, who were asked to provide comprehensive details about their technologies, focusing on aspects directly relevant to the chosen use cases.

As a key objective of the project was to facilitate knowledge sharing among NRAs within CEDR, substantial efforts were made to gather the experiences of the NRAs who had implemented selected technologies. This was achieved through in-depth interviews with the NRAs who had implemented the identified technologies. Prior to the interviews, the NRAs were provided with a fact sheet template, allowing them to familiarize themselves with the format and prepare for the discussions. These interviews provided valuable insights into their experience and practical application of new technologies. In addition to pre-determined questions based on the fact sheet template, additional inquiries were made to explore specific aspects of their implementation in greater detail.

WP4 provided the following Deliverables:

- Case Study catalogue and Case Study report (D4.1)

2.4.6 Work Package 5 (WP5)

Roadmap and Self-Assessment

The main objectives of WP5 were to develop frameworks that help NRAs to produce organisational and technological roadmaps for the implementation of new technologies. The framework for an organisational roadmap aims to help NRAs to assess their appetite, capabilities and organisational procedures for innovation, as shown in Figure 6.

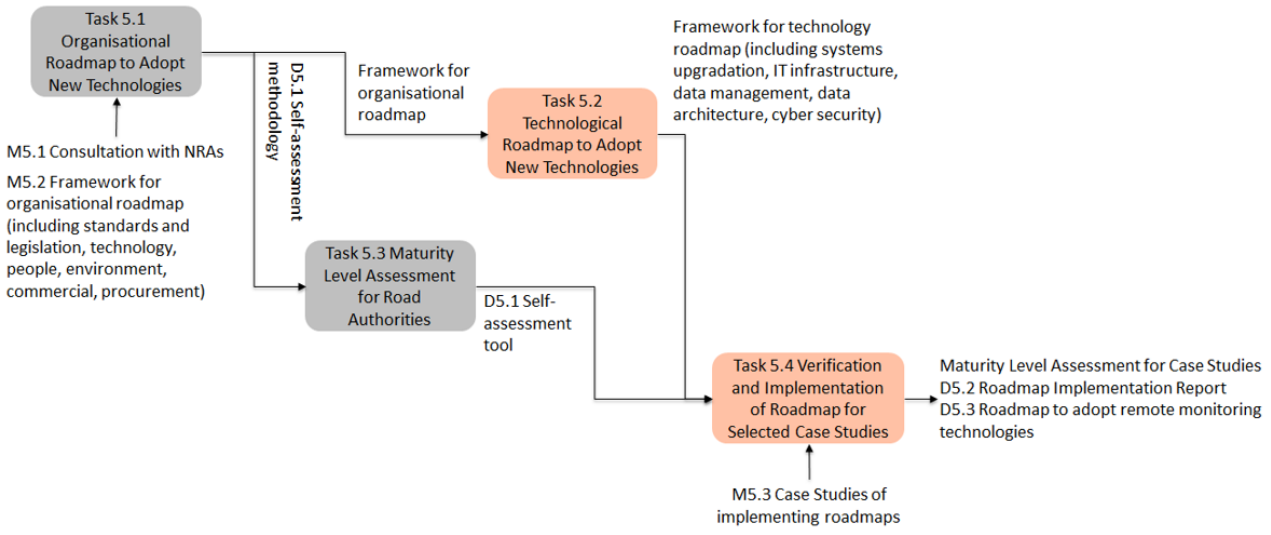


Figure 6: Flow chart for Organisational Roadmap, Self-Assessment and Implementation Plan.

INFRACOMS followed slightly different approaches to develop the two streams

- To provide guidance in the development of a framework for organisational roadmapping the expertise of partners was combined with various exisiting standard processes to develop a methodology to help an NRA self-assess their organisational capabilities with respect to implementing new technology. The approach reflected in the final version of the INFRACOMS appraisal methodology and self-assessment tool reflected a number of the principles of the ISO 56000 series of standards for innovation.
- The development of a framework for technology roadmapping was broadly based on the expertise of the partners, a variety of sources and discussion with NRAs.

INFRACOMS used various methods and means of interaction to incorporate NRA feedback, to refine the development of these frameworks:

- A small consultation at an early stage with NRAs in general and separately with the Norwegian and UK NRAs;
- Additional consultation (a survey) with NRAs during the early stages;
- Intensive interaction with the Norwegian and UK NRAs to review and consult on the methods;
- Presentations at dedicated workshops (WS2 – WS6);
- Interactive practical sessions in dedicated workshops (WS2 – WS6);

As for the outcomes of the previous WP, these frameworks were implemnted into the confluence toolkit. In adition WP5 provided the following Deliverables:

- Self-Assessment Methodology for NRAs (D5.1)
- Roadmap implementation report & Roadmap to adopt remote monitoring technologies (D5.2/5.3)

2.4.7 Work Package 6 (WP6)

Dissemination

WP6 implemented a comprehensive dissemination strategy to communicate the project objectives, progress, and outcomes to a broad audience. At the heart of this strategy was the creation of a visual identity, marked logo used consistently across all project materials. A project flyer was developed to present the project's goals and was distributed at dissemination events.

A dedicated project website (www.infracoms.project.cedr.eu) functioned as a central communication hub, providing stakeholders and the public with up-to-date information on project activities, deliverables, publications, newsletters, and upcoming events. The project also leveraged social media platforms, particularly LinkedIn, using existing accounts like TRL's to maximise visibility and reach. Relevant hashtags were employed to enhance the impact of posts and ensure broader dissemination.

Regular communication with stakeholders was maintained through the release of four half-yearly newsletters, which covered a range of topics such as current practice, data interpretation, technology appraisal, and future roadmaps. These newsletters were distributed via email, published on the project website, and shared on social media. A formalised stakeholder group was established, including NRAs, infrastructure managers, technology developers, and academic researchers. This group was actively engaged through targeted consultations and online workshops designed to gather insights and present project tools and roadmaps.

Three online workshops were facilitated to demonstrate tools to collect feedback from and present the technological roadmap to CEDR member NRAs. Project results were disseminated at prominent

conferences, including the PIARC World Road Congress 2023, ERPUG 2023, the Transport Research Arena (TRA) 2024, CETRA 2024, and IABMAS 2024 through paper submissions and presentations. Although there had initially been a plan for three regional workshops, it was recognised that there has been a shift to hybrid working and on-line webinars. Therefore, the project adapted to hold one in-person workshop, supplemented by an individual NRA online training session and one online training session for a wider audience, ensuring effective training and dissemination of the project's outcomes to NRAs.

As the project approached its conclusion, a final event organised by CEDR provided a platform for presenting the results, with all work package leaders and key stakeholders in attendance.

Preparation for the follow up demonstrator projects

INFRACOMS has provided a worked example of a potential future project that could be undertaken to practically demonstrate the implementation of a technology identified by the project. A technology which had passed through the appraisal process in WP2, was assessed for integration in WP3, and had a business case analysis undertaken in WP4 was selected for this demonstration – the COWI CVI bridge inspection system. The demonstration case project report presented a costed proposal for the demonstration of this technology on a bridge in Norway. This described the practical activities that would be undertaken to carry out the demonstration, and the outcomes that would be expected.

WP6 provided the following Deliverables:

- Dissemination and Exploitation Plan (D6.1)
- Demonstration case programme and cost estimate Report (D6.2)

It should be noted that the INFRACOMS website contains records of all reports and dissemination:

- Deliverables and publications: https://www.infracoms.project.cedr.eu/reports-deliverables
- Events: https://www.infracoms.project.cedr.eu/events
- Newsletters: https://www.infracoms.project.cedr.eu/newsletter

3. Possible ways forward (solutions)

INFRACOMS has provided an online tool within the Confluence platform that can be deployed by NRAs to catalogue new technologies, undertake appraisals, develop organisation and technological roadmaps. Importantly, as an online tool, the platform enables NRAs to share the knowledge gained, reducing the need for other NRAs to "re-learn" the lessons of other NRAs when considering new technologies.

The data within the tool is owned by CEDR and further development and additions to the data will increase its value and usefulness. However, there is a question over the long-term support of this facility. As the Confluence platform is a commercial product it requires annual licencing fees so that is continues to be available. This is a common requirement for any such system, and would not require a large financial commitment.

However, the strength of the tool lies in the data within it. It is likely that a proactive approach will be required to ensure that the data is managed and kept up to date, and that NRAs continue to use the tool to share knowledge. This may require an ongoing commitment by CEDR. Hence a decision will be required on whether/how the tool should continue after the completion of the project.

Three options for possible ways forward are proposed. It should be noted that the different options are not mutually exclusive and can be implemented as required. The diagram in Figure 7 shows how the different options interlink.

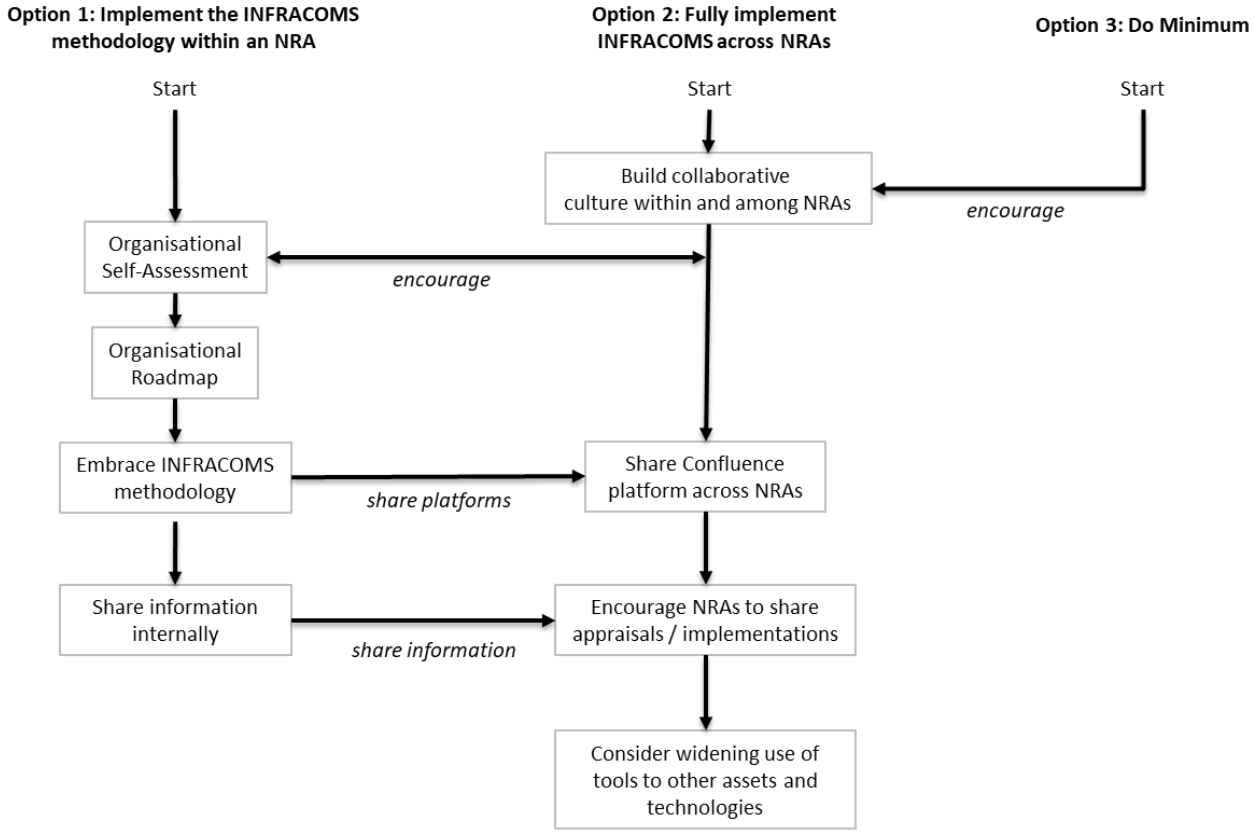


Figure 7: The three options and how they interlink.

3.1 Option 1: Implement the INFRACOMS methodology within individual NRAs

In this option it is suggested that individual NRAs could adopt the tool and determine how a collaborative, knowledge sharing culture could be developed around it within their organisation. It allows individual NRAs to progress with the self-assessment and organisational development and adopt the methodology internally at their own pace. If this is successful in more than one NRA, it would be possible to move on to wider implementation (i.e. option 2) in future by sharing the tool.

NRAs wishing to adopt the toolkit would need to procure their own licences for access to the site. The existing content would be copied into the NRA's licenced version.

To implement this option it is recommended that an NRA identify a 'champion' to lead the process. This should be someone who is invested in the process and can bring diverse groups together. In particular the innovators within the organisation should be identified and invited to join the adoption process. They focus should not be on just the asset management group.

Further suggested steps are outlined in the following subsections:

3.1.1 Step 1: Conduct an organisational self-assessment using the toolkit from INFRACOMS WP 5.1.

An NRA considering adoption of the approach would explore the tool by conducting their own self-assessment using the guidance produced in INFRACOMS report D5.1 and the Self-Assessment Toolkit. This could include internal surveys to better understand how the NRA currently operates and how innovation and new technologies could be embraced and incorporated into the culture of the organisation.

It may be that NRAs already have an innovation policy or a system in place to assess and review new technologies (there is evidence of NRAs carrying out reviews of new technologies, but INFRACOMS did not find any formal system of assessment or appraisal). Some external assistance may be needed to help NRAs identify the institutional and capacity building reforms necessary to improve.

NRAs can manage this process themselves, although there could be a role for CEDR to motivate them to do so.

3.1.2 Step 2. Produce an organisational roadmap

From the results of the organisational self-assessment, the NRA can produce an organisational roadmap that identifies time-bound action plans to improve innovation within the organisation. There is guidance in the INFRACOMS project report D5.2/5.3 to help NRAs achieve this, which should be based on the four pillars of asset management; data, technology, organisation and impact. At the very least, this should develop new, or reinforce existing, policies and procedures for innovation, including the use of the INFRACOMS appraisal methodology, and also improve the culture of innovation within the organisation.

NRAs can undertake this process themselves following the self-assessment in Step 1.

3.1.3 Step 3. Embrace the INFRACOMS appraisal methodology

Again, led by the "champion" identified by the NRA, implement the guidance and tools created in INFRACOMS to conduct appraisals and develop technological roadmaps for any new technologies under consideration to improve asset management in the organisations. This can be found in report D2.1 and the User Guide in D2.2.

NRAs can undertake this themselves using the guidance provided, but CEDR could encourage uptake of the methodology.

3.1.4 Step 4. Share information and experiences on Confluence internally.

Following the organisational assessment and adoption of the appraisal methodology, the NRA should share experiences and technical information on new technologies and their use cases internally. This will make others within the NRA aware of how and where new technologies can be used and will demonstrate the advantages of sharing information.

This would be the responsibility of each individual NRA.

3.1.5 Advantages/disadvantages of option 1:

The main **advantages** of this solution are:

a. The experience gained in INFRACOMS is sustained and the platform shared. The responsibility for licencing the platform is taken on by individual NRAs.

b. The methodology can be implemented at a pace the individual NRAs adopting the process are comfortable with.

c. Any NRAs undertaking this option will have an insight into the improvements they need to make to be able to implement new technologies.

d. NRAs can review their own organisation to judge whether they need to change their organisational set-up or processes and practices to make their organisation more innovation-friendly, which in turn would help with the implementation of new technologies.

e. NRAs can gain experience with the process before wider roll-out.

The main **disadvantages** are:

a. Local knowledge platforms will not facilitate sharing of information with other NRAs.

b. The INFRACOMS methodology is not being fully implemented so the full benefit is not being realised.

c. Individual NRAs would have to manage and moderate the platform themselves, which could be a burden in terms of people's time and availability. Each NRA would require a dedicated person to be responsible for implementation of new technologies and to be aware of innovations across their own NRA. They would need to liaise with specialists within the NRA and with technology providers to make detailed appraisals of new technologies.

d. The NRA would have to manage the site in terms of upgrades, training and dissemination.

3.2 Option 2: Fully implement the INFRACOMS methodology across NRAs

This option aims to use the project outcomes to build a collaborative culture within and between NRAs to share information on the use of new technologies. It fully embraces the tools that were developed under INFRACOMS and leverages the full benefits from sharing information between NRAs.

Collaboration and sharing of information were one of the key premises of the DoRN. Sharing of experiences among NRAs will help them to identify technologies and their use cases and evaluate and make informed decisions on whether to implement those technologies in their own organisations. Although this option covers many NRAs, as for Option 1, it is recommended that each NRA identify a 'champion' to lead the process in their organisation. This would be necessary to drive progress and coordination.

3.2.1 Step 1. Develop a strategy for collaboration / coalition within and among NRAs for the sharing of information on the use of new technologies

This initial step would develop a cross NRA strategy for sharing of lessons learnt and experience in the application of new technologies. It would identify any barriers to change and develop solutions, which could be institutional, legal, technical etc. Some of the considerations for this stage are:

a. Encourage / sponsor the development of Memorandums of Agreement (MOUs) and/or codes of practice for sharing information between NRAs, that would in the longer term lower the barriers to the implementation of the INFRACOMS processes/toolkit among individual departments of NRAs. This could be led by CEDR or an individual NRA.

b. The participating NRAs could consider undertaking a self-assessment of their capacity to adopt new technologies using the INFRACOMS approach, to help inform the collaborative discussions. They could also share experiences and key aspects of their organisational roadmaps.

c. Each NRA would need to raise/address ~~internal~~ issues of sharing information across NRAs (considering General Data Protection Regulation (GDPR) and other privacy issues).

d. Explore the lessons learnt by other organisations (such as the Nordic Road Association (NVF), which may already have examples of such data sharing or collaboration agreements).

The CEDR Innovation Working group could be in a good position to encourage and motivate this, although it is recognised that CEDR involvement at this level would require additional funding.

3.2.2 Step 2. Share the Confluence Platform across NRAs

Building on the above, a formal or informal consortium of NRAs would be created who have agreed to develop the collaborative approach towards implementing new technologies. These NRAs would implement the single INFRACOMS toolkit across their organisations. The management and funding of the Confluence tools would need to be formally agreed.

As this process requires cross-NRA commitment it will also require staff resource commitment to manage the tool, ensuring it is up to date, quality controlled, that there is technical support available etc. it is suggested that the easiest way to achieve this would be to employ an external consultant, whose role would be to manage the administration and further develop Confluence. This could include extending the scope and usability of tools, providing refresher courses in how to use the

tools, and answering queries on the use and function of the site. Moderation of information posted on the site could also fall under the remit of the external consultant.

The external consultant could also be used to provide support to NRAs wishing to use the self-assessment tool and consider ways of improving the culture or uptake of innovations in their organisation to embrace new technologies. NRAs should be encouraged to continue adding new technologies and their appraisals to the database. Membership invitations should be extended to all CEDR members. Translation into multiple languages may be necessary.

It may be desirable to form a Steering Committee within the active NRAs to manage the development of the Confluence platform.

Create a consortium of NRAs who are interested to invest in a collaborative approach towards implementing new technologies. Agree on the management and funding of the tools developed under INFRACOMS. This could be managed by CEDR (with funding from NRAs) or by an NRA that is willing to 'champion' the cause.

3.2.3 Step 3. Encourage NRAs to share historical evaluations / implementation information.

NRAs are likely to have existing reviews or trials that have been conducted on new technologies. NRAs should be encouraged to share their information and experiences, in order to build the INFRACOMS database of new technologies and implementation plans. This would require the NRA to undertake an appraisal on that technology for the particular use case to which it was put, but even if it is posted in a different format the information can be useful.

A survey could be conducted amongst all NRAs to uncover any recent reviews of new technologies. It is likely that each NRA will have to liaise with different internal departments to identify these reviews, and then liaise with the relevant subject expert to do the appraisal.

This could be a CEDR role, but will be dependent on the MOU / code of practice / terms & conditions put into practice.

3.2.4 Step 4. Consider widening use of the tools to other assets and technologies.

The current Confluence platform is designed to process information for roads and bridges, but it can also be extended to other assets and technologies, such as tunnels, drainage, geotechnical data, Information Technology Services (ITS) solutions, technology products etc.

This could be motivated by CEDR or a 'champion' NRA, given sufficient interest by NRAs.

3.2.5 Advantages/disadvantages:

The main **advantages** of this solution are:

a. The experience gained in INFRACOMS is sustained and the platform shared. The responsibility for licencing the platform (and managing it) is taken on across several NRAs.

b. Maximum impact can be made from the INFRACOMS tools through interactive sharing of information. NRAs are able to learn from the experiences of each other to avoid inappropriate implementation of new technologies.

c. Although there are costs involved in engaging an external consultant to manage the platform, this would have the advantages of having an independent moderator, and someone who can handle the administrative burden.

d. The management costs for the platform would be fixed, if the contract for the external consultant were to be on a lump sum basis. This allows the NRAs to budget reliably for this task.

e. More cost-effective asset management of roads and bridges throughout the EU.

The main **disadvantages** are:

a. This option will necessitate some administration for sharing of information,

b. NRAs will need to jointly fund any external assistance, although this should make the management of the platform less onerous.

c. NRAs will need to discuss and decide how the platform develops in the future, as there will be additional costs to, for example, expand the platform to cover additional assets or to implement additional workflows or security measures.

3.3 Option 3: Do Minimum

In this option no further development of the tools developed in INFRACOMS would be undertaken. However, it keeps the Confluence platform active through free subscriptions which allows view-only privileges.

This solution enables individual NRAs to take the solutions forward, but at minimal involvement and cost. After one or two years the active NRA may reach out to others to join. However, this means more wasted time during which the current technologies will have either become established or been abandoned, and others outside of the supporting NRA may not have been captured. This would represent a missed benefit.

This option would mean minimal support of Confluence and no sharing of experiences, for example NRAs would continue to work in silos and struggle to implement new technologies. There is likely to be duplication of efforts to trial and test new technologies and it is likely that the same mistakes will be made across NRAs. There is also a risk that new technologies will be adopted inappropriately, which can have impacts on durability and safety of roads and bridges. There is also the missed opportunity cost of applying technologies to new use cases.

3.3.1 Advantages/disadvantages:

The main **advantages** of this solution are:

a. This is the cheapest option and gives the NRAs some time to decide how they want to proceed.

b. In addition to keeping the platform ‘alive’, the tools developed under INFRACOMS will be provided as standalone copies, for example the Database and appraisal tool will be provided as data, and the self-assessment tool will be a spreadsheet.

The main **disadvantages** are:

a. There is no mechanism to actively share information on new technologies, which would have been the biggest advantage of the INFRACOMS outputs.

b. Information on new technologies quickly becomes out of date, so a ‘slow’ uptake of INFRACOMS tools will make it difficult to stay abreast of new technologies and their uses.

c. The momentum provided by INFRACOMS may be lost if not acted upon quickly. This could result in the tools and outputs not being used to their full potential.

d. The potential impact on NRAs includes wasted resources and time to trial new technologies that may not be appropriate or adopting technologies that do provide relevant outputs for a

particular use case. These issues could be mitigated or avoided by an active adoption of INFRACOMS tools.

e. It is unlikely that this option will lead to any transformative behaviour in how NRAs review and adopt new technologies.

4. Comparison of the possible ways forward

This chapter considered the advantages and disadvantages of each of the options considered in the previous chapter, in the context of sustainability and the three pillars which drive sustainable development and the sustainability goals for CEDR.

4.1 Pillars of Sustainability

The three pillars of sustainability are:

- **Pillar 1: Economical**: Economic sustainability requires businesses to balance profit with environmental and social considerations.
- **Pillar 2: Societal**: Social sustainability focuses on equity, justice, and community well-being.
- **Pillar 3: Environmental**: Environmental sustainability involves managing resources and reducing pollution.

The pillars are shown in Figure 8. They are otherwise known as Profit, People, and Planet. Sustainable development can be achieved only when environmental protection, social equity, and economic profitability coexist without one area taking over any of the others.

However, the options for ways forward are focused on the development of an innovation culture and implementing new technologies as effectively as possible within NRAs. In this respect the options themselves could only be scored on an economical basis, and this would take some detailed cost-benefit analysis. To score on a societal and environmental basis would mean considering the new technologies themselves, which is not the aim of this chapter. Therefore, achieving a meaningful scoring would be impractical.

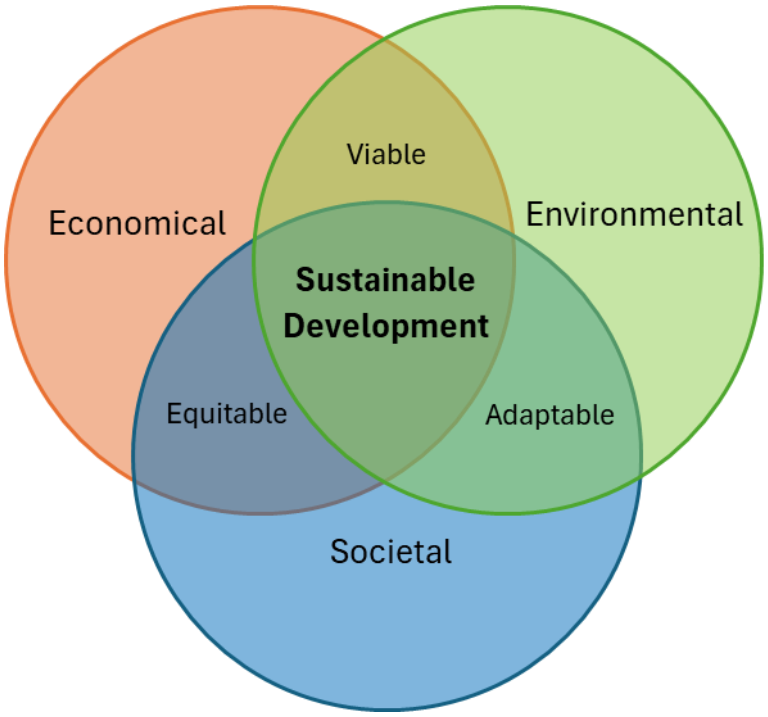


Figure 8: The three pillars of sustainability.

The benefits of the outputs of INFRACOMS are assessed below:

Pillar 1: Economical:

Sharing information on evaluations of new technologies among roads agencies can yield substantial economic benefits, by optimizing resource use and accelerating the adoption of effective solutions. When agencies collaborate and share evaluation data, they can reduce or eliminate the need for redundant trials and testing, resulting in significant cost savings. These savings arise from reduced expenditures on materials, labour, equipment, and operational overheads. By streamlining the evaluation process, agencies can reallocate these financial resources towards other critical infrastructure projects, thereby enhancing overall economic efficiency, and also contributing to social and environmental benefits as discussed further below.

Expedited adoption of successful technologies can lead to quicker realisation of cost-saving benefits. For instance, technologies that improve traffic flow and reduce congestion can lower fuel consumption and vehicle operating costs for both individuals and businesses. This not only saves money for road users but also boosts productivity by reducing travel time and increasing the efficiency of goods and services transportation. The ripple effect of these improvements can stimulate local economies, as businesses can operate more effectively, and commuters can allocate saved time to more productive activities.

Shared information also helps agencies make more informed and strategic investment decisions. Access to a broader pool of evaluation data allows for a better assessment of the cost-effectiveness and return on investment of various technologies. This ensures that public funds are spent on solutions with proven economic benefits, thereby maximising the impact of infrastructure spending. Furthermore, by reducing time and effort spent on ineffective or suboptimal technologies, agencies can prevent costly mistakes and ensure that infrastructure improvements deliver the anticipated economic gains. Liaison between NRAs may also facilitate shared implementation across NRAs, achieving economies of scale.

- **Pillar 2: Societal**:

Collaboration and sharing of information fosters a culture of transparency and accountability among public agencies and with the wider public. When roads agencies share their findings openly, it builds public trust by demonstrating a commitment to using the best available knowledge to make informed decisions. This transparency helps to strengthen the relationship between the community and the agencies responsible for their infrastructure, as road users and the wider community can see that efforts are being made to optimize resources and deliver the highest quality services. Additionally, through implementation of innovative monitoring technologies, agencies should be able to better plan for maintenance of existing assets to provide better infrastructure for the communities they serve.

- **Pillar 3: Environmental**:

Sharing information on evaluations and experiences of implementing new technologies among NRAs offers significant environmental benefits. These can include reducing redundant efforts and promoting the efficient use of resources. Agencies can potentially avoid duplicating trials and experiments, leading to a reduction in the consumption of resources such as fuel, materials, and energy. This collaborative approach minimizes the environmental impact associated with conducting multiple, independent evaluations. Also, agencies can select the most effective and sustainable materials from the outset, reducing waste and the need for subsequent corrective actions. Additionally, fewer field tests might be required, which lowers emissions from vehicles and equipment used during trials and minimizes disruptions to natural habitats.

Shared evaluations can enable faster implementation of proven environmentally-friendly technologies, enabling quicker realisation of their benefits. Agencies can disseminate best practices for deploying and maintaining green technologies more swiftly, ensuring broader and more

immediate environmental improvements. Access to a larger pool of evaluation data supports informed decision-making, allowing agencies to choose technologies with demonstrated environmental benefits and conduct holistic impact assessments before implementation. Sharing methodologies or cost-benefit analyses which take account of environmental impacts can also lead to improved decision-making and sustainability.

Widening out to other technologies (not just condition monitoring) could bring additional benefits around faster implementation of transport services, leading in turn to reduced congestion and reduced environmental impacts associated with traffic delays.

Summary

In summary, the collaborative sharing of evaluation information and implementation experience among roads agencies provides many economical, societal, and environmental benefits. Economically, this practice reduces redundant testing, optimizes resource allocation, and accelerates the adoption of cost-saving technologies, thereby enhancing the efficiency and productivity of infrastructure investments. Societally, it fosters faster implementation of safety and environmental improvements, helps build public trust through improved transparency and accountability, and ensures that communities experience enhanced quality of life with better road safety and reduced congestion. Environmentally, such collaboration can minimise resource consumption, lower the ecological footprint of trials, and promote the swift adoption of sustainable practices and technologies. Together, these benefits combine to help create more effective, reliable, and sustainable transport systems.

4.2 Comparing the benefits of each option

The DORN highlighted several aims for the INFRACOMS project, in response to the issues that were being experienced by NRAs. The issues identified can be summarised as:

- Lack of timely information on road asset condition and performance, resulting in premature deterioration and even failure.
- Lack of deterioration information on the life of infrastructure assets, leading to inefficient maintenance and repairs.
- Some data cannot be exploited to their potential because it is not properly integrated with additional information.
- RAMS architectures may not be structured to easily accommodate new data sources and the data may not be validated or cleansed sufficiently to provide robust information.
- Existing methods have some limitations since they are not always i) able to provide all needed data, ii) able to access all locations and iii) economically effective. In some cases, the measurement method is used with a sampling rate lower than the rate of change in physical properties and a different application of the method might become too expensive.

Some of these limitations can be overcome by the implementation of alternative solutions capable of providing additional information and flexible usage. For example, the Internet of Things (IoT) has the potenital to transform asset management towards a more integrated system where conventional and innovative data sources and uses become complementary.

We have developed the outputs and tools in INFRACOMS with the goal of satisfying the aims, which can be summarised as:

- Improve European road operators knowledge and understanding of remote asset condition monitoring and data collection to make lifecycle asset management decisions.
- Enable European road operators to strategically implement innovative technologies and approaches to remote asset condition monitoring and inspection, focusing on the greatest need and delivering the maximum value.
- Improved and efficient asset management and maintenance activities which extend the life of assets and avoids asset failures, for a safer, more reliable and more sustainable European road network.
- Help to lower operating and capital costs by facilitating proactive servicing and repair of assets, while allowing more efficient use of resources and reducing traffic disruption.
- Enable real-time remote monitoring.
- Improve detection and prediction of structural failures.
- Improve accessibility of information on transient physical properties.

We have considered the main benefits that could flow from the three options given in Section 3 to embrace new technologies in European NRAs, in line with the three pillars of sustainability. These are shown in

Table 1 below, with the potential for each benefit to be realised indicated by ticks. A dark tick means that the benefit can be fully realised if that option is followed, a light tick indicates it could only be partially realised, and no tick means that the benefit cannot be realised.

It can be seen that Option 3 has no benefits as the tools are not being used and there is no sharing of information. Option 1 has some benefits in all categories, but most do not have the potential to be fully realised because there is minimal sharing of information between NRAs. Option 2 has the most benefits because it fosters a culture of innovation and sharing between NRAs and enables NRAs to make informed decisions on implementing new technologies.

Table 1: Assessment of the benefits related to each option

Benefits	**Option 1 – Within an NRA**	**Option 2 – Across NRAs**	**Option 3 – Do Minimum**
Pillar 1 - Economical			
Optimise resource use	✓	✓	
Faster cost-saving benefits	✓	✓	
Cost effective transport services	✓	✓	
More informed investment decisions	✓	✓	
Pillar 2 - Societal			
Fosters a culture of transparency	✓	✓	
Building of trust with the roads agencies	✓	✓	
Strengthens relationships with community	✓	✓	
Interventions focus towards the community	✓	✓	
Pillar 3 - Environmental			
Efficient resource use	✓	✓	
Avoid duplication and reduce consumption	✓	✓	
Promote sustainability	✓	✓	
Reduce emissions and waste	✓	✓	
Rapid uptake of environmentally friendly technologies	✓	✓	
Environmentally aware decision making	✓	✓	
Environmentally efficient transport services	✓	✓	

✓ = Potential to be fully realised

✓ = Potential to be partially realised

5. Final Event

The INFRACOMS Final Event was held in Oslo on 23rd and 24th October 2024, hosted by the Norwegian Public Roads Administration (NPRA) and CEDR. The Agenda for the final meeting can be seen in Annex A. The first session was hybrid, and the remaining sessions were held in-person.

5.1 Session 1:

The first session was a presentation of the project results and outcomes. It was shared in a hybrid format with the people present in the room, plus others who joined online. A list of participants can be seen in Annex B.

The results were presented in the order of the Work Packages, as illustrated in Figure 1, shown previously in Chapter 2. The presentations were as follows:

- Introduction to INFRACOMS – Robin Workman and Alex Wright (TRL)
- WP1: Practice, Future Needs and Gap Analysis – Anna Arvidsson (VTI)
- WP3: Data Interpretation and Visualisation – Mogens Saberi (COWI)
- WP2: Appraisal of New Technologies – Kevin McPherson (TRL)
- WP4: Technology Case Studies – Simon Fjendbo (DTI)
- WP5: Road Maps – Robin Workman (TRL) and Andrej Anžlin (ZAG)
- WP6: Demonstration and Dissemination – Ali Yeganeh (BRRC)

The results can be seen in detail in the reports posted on the Confluence tool.

The results and deliverables were discussed and any issues clarified.

5.2 Session 2:

The second session was conducted with the participants present in the room only. This session included two main presentations, followed by a discussion, as follows:

Presentation 1 by Heine Toftegaard (NPRA) and Siri Hustad (NPRA) on new technologies that NPRA would like to share on Confluence. The presentation focused on data collection of traffic to inform the maximum weights of heavy vehicles and how they would impact the pavement and bridge performance. They have developed a data flow process. There is concern over continuous heavy loads and the pumping effect on the road structure. Traffic load modelling is considered, with increased traffic resulting in higher levels of fatigue. It was suggested that NPRA could look at existing case studies of Weigh in Motion in Confluence to inform their current project.

NPRA would like to include these technologies in Confluence so that when policies are drafted there is a single point of reference for new technologies. Confluence could be used as a tool to provide evidence for NRAs trying to establish a business case for a new project, for example it could show this has not been done before, or it could provide evidence to support the design of a proposed study.

Presentation 2 was made by Kevin McPherson on the three options for implementing the INFRACOMS methodology, as presented in Figure 7 of Chapter 3 of this report. This session was designed to demonstrate the three options for moving forwards over the 1-year PEB extension for INFRACOMS, and what barriers there might be to implementation both now and in the future. A discussion session was held immediately following the presentation. The options presented were:

Option 3 was shown first as the 'Do Nothing' option, although it was presented as a 'Do Minimum' option because it would still be necessary to take some actions to keep the toolkits alive. However, this is the least preferred option as much of the benefits of the systems developed would not be realised.

Option 1 would involve a single NRA following the INFRACOMS methodology and taking responsibility for using the tools and reporting back to the PEB on progress. This includes a higher number of licenses for Confluence for the internal participants of the NRA, and any necessary training.

Option 2 was presented as the ideal solution that was envisaged when the INFRACOMS methodology was developed. This includes all NRAs having full access and actively using the methodology and tools in the way they were designed.

It was stressed that these options are not mutually exclusive and can be combined in a number of ways. Also, it would not be necessary to involve the consortium if CEDR or a group of NRAs wanted to take on the management.

Note: license costs are based on invoicing to a single entity, not to each NRA individually, which would incur additional administration.

The costs for CEDR/NRAs to implement these options using the consortium were presented and are shown in Table 2.

Table 2: Costing of different options

Option 1	Option 2	Option 3
Costs		
25 licenses = €1,800 p.a.	38 licenses =€2,736 p.a.	20 licenses = €1,440 p.a.
2 days p.m. €34,405	>3 days p.m. min. €48,908	1 day p.m. €17,743
Tasks included		
Manage licenses/guests	Manage licenses/guests	Manage licenses/guests
Launch event	Launch event	Launch event
Check/moderate content	Check/moderate content	Check/moderate content
Inform of updates	Inform of updates	Inform of updates
Liaise with PEB for plan	Liaise with PEB for plan	Liaise with PEB for plan
Training to new licensees	Training to new licensees	
Moderate additional content	Moderate additional content	
	Modify tool for new classes	
	Quarterly newsletter	
	Online user conference	
	Assistance to post reviews	

It was recognised that PEB need some time to decide on the future of INFRACOMS. The Consortium agreed to finance one more month until the end of November 2024, after which the PEB and CEDR will need to take responsibility for the site, either directly or through a supplier.

Identification of barriers:

The discussion focused on identifying the barriers to implementation. The key barriers identified include:

- Time: PEB members consistently said they did not have enough spare time to commit to the tools and carrying out reviews.
- Responsibility: Some PEB members acknowledged that they were not the right person to take responsibility for the outputs. Some had tried to find an appropriate person but were not able to get them to take responsibility.
- Sharing of information/data: There may be some issues with sharing of information and data among NRAs.
- Confidentiality: Some information is sensitive and cannot be shared, which was especially true for the Self-assessment review toolkit.
- Language: The tool has been made in English as it is the common language within CEDR, but many countries must officially use their own language for such tools and reviews, which could pose a problem, or at least a barrier to transfer knowledge to English in Confluence. This could also be a problem for countries with more than one official language, who may wish to have an option to show the site either language.
- Policy/Procedures: At present the INFRACOMS methodology and tools do not appear in policy or procedures, which means there is no obligation to use them.
- Cost: Some expressed an issue with cost, although the annual costs presented when divided between several NRAs are very low. The main issue may be the administration and approval of the spending.
- Lack of engagement: INFRACOMS has struggled to attract interest beyond the PEB, despite the dissemination activities. However, there has been some interest from outside Europe, which is explored later.
- Lack of awareness: Lack of awareness is similar to the engagement issue. Despite the conference presentations, website and other dissemination activities INFRACOMS has failed to establish a high profile. This is partly because the conferences presentations are limited to a short presentation or a poster event, competing against many other presenters.
- Limitations within Europe: So far, the reach of INFRACOMS has been limited to CEDR, but there may be a wider interest worldwide, as many countries and agencies encounter similar issues.
- Usefulness: Those involved with INFRACOMS agree it is useful, but this relies on it being kept current and all users actively contributing to it.
- Too much work involved in evaluations: The full evaluations can take a day or more to complete, and need external information, so can be quite onerous.
- Obtaining information on new technologies: In general suppliers will provide information readily, but information on performance can be harder to obtain.

- Information may be out of date: It is necessary to have current information to keep the site valid.

Discussion:

Discussed whether NRAs could mandate the use of the INFRACOMS database before new technologies are used? May be possible, depending on the NRA.

Officially licence holders can invite up to 5 guests each, but not good practice to convert licence holders to guests (Confluence discourage it).

Wider parts of the NRAs should also be involved, such as Innovation Units, who may have more motivation to use the tools.

There is evidence that some NRAs have done their own appraisals of new technologies, which should be incorporated into the INFRACOMS database.

If the system could be accessed through an NRA intranet it could make it easier to use.

Maybe the people involved in INFRACOMS are too senior, perhaps a lower-level employee would have more time and motivation to do appraisals and liaise with other NRAs?

There should be a motivation for suppliers to provide data for updating.

There may be a possibility for the updating of INFRACOMS to be self-funding if it is popular and suppliers want to be included in it. However, the general indication throughout the INFRACOMS project is that the toolkit should be impartial and should focus on evidence and experience of NRAs.

Accreditation by the industry could be possible to retain independence.

5.3 Session 3:

This session included three presentations that were designed to show how new technologies can be implemented. This set the scene for a discussion on how to find solutions to the barriers identified earlier.

The Presentations were:

- PAS2161 Shift to the new DfT (UK) condition data collection and assessment regime: TRL. – Alex Wright. PAS2161 provides the requirements for the collection, codification and reporting of road condition monitoring data for national reporting. The PAS does not require the use of a specific type of technology for the collection of RCM data, but categorises various types of technology that can be deployed for the collection of RCM data.
- Remote condition monitoring on Swiss National Road pavements - *ASTRA – Federico Irali.* The Swiss network is trialling NIRA technology to measure roughness in IRI on two sections of road with high traffic and known problems. They are planning to extend the trial next year to 500km of road. This raised the question of whether users want results or raw data, which varies between NRAs. Indeed, how is raw data defined? Maybe a universal definition is needed.
- Netherlands presentation on bridges - *SHMnext – presented by: TUD Yuguang Yang.* Magnetic sensors are being trialled on steel bridges in the Netherlands. They are designed to identify early cracks and fatigue in steel bridge members. They listen for small noises that can indicate cracking and the progress of cracks. In some cases, the cracks were not where

they would be expected. In this case it would have been useful to have this information in an INFRACOMS appraisal.

Questions and clarifications were taken on these presentations, before the break.

5.4 Session 4:

Session 4 was facilitated by Yuguang Yang of TUD.

Solution to Barriers:

The aim was to discuss further the barriers and identify some potential solutions, and to go through the Technological Roadmap process in more detail:

- Time/Responsibility: For NRAs to allocate time and responsibility to appropriate individuals to manage their input to INFRACOMS. This would include adding evaluations as necessary, scanning the database for new technologies, liaising with suppliers and other NRAs, etc. As suggested before this could be a mid to low level employee who has the time available.
- Sharing of information/data: It may be possible for NRAs to share MoU's among themselves, or use other more formal agreements. This would need to be done within the umbrella of GDPR and data sharing.
- Confidentiality: Some guidance on maintaining confidentiality may be necessary.
- Language: There are online tools available for translation than could be used to help provide multiple versions of evaluations and information in Confluence. Some browsers provide translation of web content, but this would be independent of Confluence. Any documents uploaded in a different language could be tagged with the language used.

  In Confluence, the administrator assigns the default site language and individual users can choose a display language that's different from the global default (English). The language a user sees will depend on the following factors, in order from highest to lowest importance:

  - The language preference set in the user's profile. Users must be logged in for this setting to take effect.
  - The language preference set in the user's web browser, as detected by Confluence.
  - The default language for the instance, as defined by a Confluence administrator.

  However, this will only change the language of the general text and system messages, not the 'Project' text. Confluence suggests the use of (paid) add-ons which can translate pages automatically, or (manual) browser-based translation tools: How to translate Confluence page content | Confluence | Atlassian Documentation

  The main language issue would need to be resolved by CEDR and users of the INFRACOMS tools on a country basis. This may need some compromise by NRAs in how they access and provide information for INFRACOMS.
- Policy/Procedures: It was suggested that a requirement to consult the INFRACOMS database be made mandatory when implementing new technologies. This would be to check whether the technology has been used before, and how, and whether there are any viable alternatives. There was also a suggestion that it would make the process easier if INFRACOMS tools and information could be provided through an NRA Intranet.

- Cost: The possibility to get suppliers to pay for part or all of the INFRACOMS tools and maintenance was suggested. There are potential issues with this approach, for example maintaining impartiality in the evaluations and preventing the tool being used for promotional purposes by suppliers. Nevertheless, it would be reasonable to expect suppliers to contribute towards the costs of technology appraisal.
- Lack of awareness and engagement: A launch event for INFRACOMS has been proposed as part of all Options. This would explain and promote the platform, but to be effective would need to be promoted through CEDR and PEB members. Promotion through social media and other online outlets would also be essential for this. Over the course of the next year, it would be beneficial to promote INFRACOMS tools at relevant events and conferences with a dedicated or shared stand, perhaps managed by CEDR and/or NRAs.
- Limitations within Europe: To date, there has been interest from international partners outside of Europe, promoted by TRL. With CEDR's approval, guest access to the Confluence site has been provided to the following:
  - SANRAL: South African National Road Agency
  - ESA: Ethiopian Roads Authority
  - UN Global Platform
  - Asian Development Bank
  - FCDO: Foreign, Commonwealth and Development Office (UK)
  - European Space Agency

  These agencies were interested to see how the new technologies were appraised and the information stored, as they also face issues with implementing new technologies with minimal information on how they are used and how they benefit the client.
- Usefulness: The key to INFRACOMS being useful is to provide up to date and impartial information on the implementation of new technologies and making this information easily available to other NRAs. There would be advantages in promoting the benefits of this knowledge and highlighting the risks of not using INFRACOMS, for example implementing a technology that does not work as presented, and not using a technology that could bring significant benefits to an NRA.
- Too much work involved in evaluations: In the short term it was suggested that NRAs concentrate on doing pre-appraisals and making their experiences available to others. This would stimulate interest in INFRACOMS and keep it current. In the longer term, full evaluations can be carried out, but the process to conduct them could be made simpler if this would benefit NRAs.
- Obtaining information on new technologies: There may be opportunities to leverage the resources of suppliers to provide information on new technologies. In general, they are happy to provide information on their technologies, but this needs to be moderated to ensure it is impartial and not misleading.
- Information may be out of date: All appraisals are date stamped, so it is easy to see in the tool how old they are. The principle of the tool is that it is a living facility and relies on current and relevant information. It would be beneficial to have notifications to all users every time a

new technology is evaluated and added to INFRACOMS. However, even if an appraisal in the toolkit is, say, 2-3 years old, then any limitations or constraints documented against the technology can still be useful information for discussion with implementors or suppliers.

- Additional suggestions: It was suggested that NRAs carry out 'Horizon scanning' activities on a regular basis, to ensure that all relevant new technologies are being captured. This could involve using social media and other communications outlets at their disposal.

Technological Roadmap:

Robin Workman went through an example Roadmap in the Confluence tool for NIRA and added in comments and suggestions. The full data can be found here: Tyre Grip Indicator (TGI) by NIRA as potential replacement for network-wide Sideways Force skid resistance measurement - INFRACOMS Knowledge Base and Appraisal Portal - Confluence

The summarised comments can be seen in Table 3.

Table 3: Roadmap elements

Roadmap Element	Actions
Risk Management	Risks include the following: ▪ Legal, data privacy, ownership of data, data control (sensitive), data security, data too frequent to act on immediately - is data publicly available? ▪ Access to third parties…. how to protect yourself? ▪ Becoming dependent on external data providers (licences), i.e. single party in the market, reliance on single supplier ▪ External factors: Weather, etc. ▪ False positives during an analysis. ▪ Sustainability of the technology, will the supplier be there long-term? ▪ Reliance on the function of the technology, not the supplier. ▪ Reputational risk. ▪ Standards keeping up with the technology. ▪ External pressures on using the data.
Cost-Benefit Analysis	The following should be considered: ▪ Higher frequency of assessment. ▪ Optimise maintenance strategy to save costs. ▪ Potential cost savings. ▪ Economic impact of blocked access. Bridge vulnerable areas are important for access. Monitoring critical infrastructure and remote areas is important. Early intervention can be cost effective. Secondary considerations; Includes circular economy.
Legal Regulatory	Issues can be: ▪ Regulations not keeping up with the technology. i.e. Drone regulations, important to define the use case for the technology.

	▪ Anonymised data and data security, i.e. blanking out number plates (on raw data?). ▪ Limit on how long you can store data and how data is stored. ▪ Liability via knowledge of issues. Needs to be specified clearly.
Policy / Standards	Department of Standards often exist at a national level. Need better awareness of these. Is it possible to develop standards for NRA's own use? Standards may apply not only to roads. Some write own standards, others use third parties. May need to revise standards regularly for some technologies? Necessary to train in use of the technology and awareness of policies/standards. May be possible to get information from suppliers also. Standards may not be consistent between departments. Do municipalities have the capacity to develop standards? Is there a National Standards body?
Procurement	Are sole suppliers allowed, or competitors to the provider, depends on local procurement rules. Example, one NRA had to teach the suppliers to produce the necessary outputs as they were procured on the basis that they could do that. Lessons learned: write tighter scope of services, check references, extra milestones, close monitoring, get supplier to demonstrate their competence.
Digital	Things to consider: ▪ Data storage. ▪ Compatibility with a RAMS. ▪ Maybe create an API to manage data internally.
Safety	Some technologies reduce safety risks, others increase them. Depends on type of technology, i.e. drones, big data, etc.
Environment	Potential issues: ▪ Noise. ▪ Wildlife impact. Better information can be positive. Important to prevent unnecessary interventions, which can lead to better traffic flow, reduced emissions, etc.
Operational Capacity	Need a clear strategy. Need external advice for new technologies, i.e. machine learning. Either build own capacity or use externals. Facilitate training.

5.5 Session 5:

This was a wrap up and summary session and focused on the way forwards. The following main points can be used to inform the PEB's decision on deciding how to move forwards, either alone, with one of the proposed Options, or as any combination of those:

- NRAs need to allocate a role for an appropriate person for INFRACOMS within their organisations.
- Appraisals should be as simple/easy as possible, suppliers can be involved to provide data and help with the drafting.
- Look at automatic translation to/from other languages where necessary.
- Promote the benefits of the tools, demonstrate how new technologies can reduce costs.
- Involve more relevant departments/units within an NRA, for example an 'Innovation Unit', to use and/or manage the tool.
- Focus on pre-evaluations in the short term to keep the tool current and useful.
- Share information between NRAs, including who the main contact persons will be.
- Explore the possibility of liaising with NRAs or other agencies such as research institutions or development banks outside of Europe.

6. Conclusions

This programme aimed to undertake research into new technologies on the remote monitoring and inspection of physical road assets, providing advice on implementing new techniques as business practice. The INFRACOMS project was undertaken to deliver these aims. The project was broadly undertaken to plan and to time, including the consultation, analysis and development phases. INFRACOMS initially proposed to provide the advice on implementing new technologies as a spreadsheet tool. However, in the light of improved knowledge sharing tools, this was upgraded to an online Wiki. This should provide a more sustainable and interactive tool, and has enabled the key tools (database, appraisal toolkit, road mapping frameworks) to be implemented in a way that can be made widely available to NRAs. INFRACOMS has also delivered all the required formal documented reports.

The data within the tool is owned by CEDR and further development and additions to the data will increase its value and usefulness. However, the site (Confluence) will require licencing and support if this is to be a sustainable solution for NRAs. Hence a decision will be required on whether/how the tool should continue after the completion of the project. This may require an ongoing commitment by NRAs and/or CEDR.

Three options are proposed for INFRACOMS going forwards. These options scale in intensity in relation to the wider commitment of NRAs to using the tool and sharing of knowledge. The three options have been compared by assessing the potential benefits to CEDR organisations, with the most comprehensive option (Option 2, which rolls the INFRACOMS toolkit out more widely and promotes more collaboration among NRAs) providing the most benefit. This option would require effort and funding for NRAs to implement, but it also returns the most value in terms of both the funding already invested in the project, and the improvements in efficiency going forwards.

References:

Abe, H., Ashiki, T., Suzuki, A., Jinno, F. and Sakuma, H. (2007), 'Integration studies of business modeling and roadmapping methods for innovation support technology (IST) and its practical application to real-world-cases', Portland International Conference on Management of Engineering and Technology (PICMET), 5-9 August, Portland OR.

American Society of Civil Engineers (ASCE). (2017). "Infrastructure Report Card." American Society of Civil Engineers.

Eggers, W. D., and Skowronski, J. (2018). "The Future of Infrastructure Systems: Smart and Resilient." Deloitte Insights.

Federal Highway Administration (FHWA). (2019). "Pavement Management Roadmap." Federal Highway Administration. Pavement Management Roadmap (dot.gov)

Heim, U., Heuss, R. and Katzir, T., (2017) 'Building an integrated technology road map to drive successful innovation' Available at: https://www.mckinsey.com/capabilities/operations/our-insights/building-an-integrated-technology-road-map-to-drive-successful-innovation#/ Accessed: 13 February 2024.

Phaal, Robert et al. "Technology roadmapping—A planning framework for evolution and revolution." Technological Forecasting and Social Change 71 (2004): 5-26.

Schachter, H. (2005). "Technology Roadmapping: A Guide for Government Foresight." Technology Analysis & Strategic Management, 17(2), 153-173.

TII, (2020) 'Guidelines for the Implementation of Innovation', Transport Infrastructure Ireland (TII) Publications, Standards and Research Section, Dublin.

Annex A: Final Event Agenda

INFRACOMS Final Event

23/24 October, 2024

Thon Hotel Vika Atrium Oslo, Norway

MAIN AIMS of the event:

- Presentation of Results (to confirm the key outputs/outcomes of the project)
- To agree a way forwards for uptake of the INFRACOMS methodology by NRAs, including continued use of the Confluence platform, how to moderate it and keep it up to date as a sharing platform.

Day 1

13:00 Lunch

Session 1 – hybrid

14:00 Presentation of results: Ensure everyone is familiar with the outcomes.

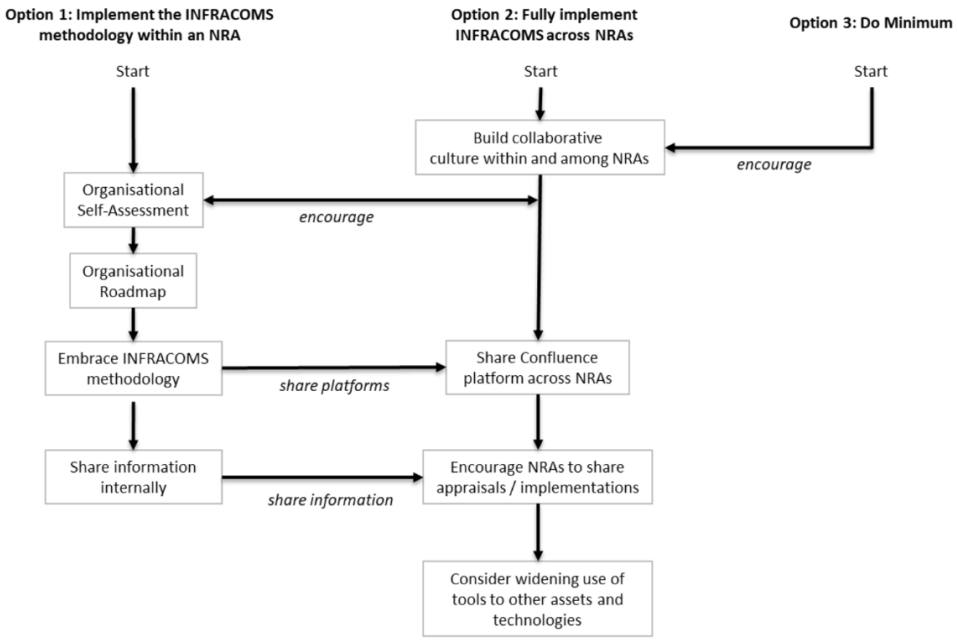
All consortium members to present on the work packages they managed.

14:45-15:00 Break

Session 2 – in-person

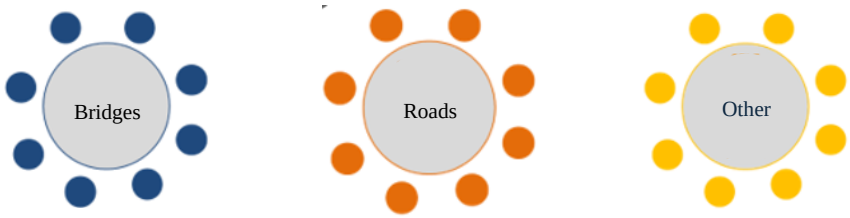
16:15 Presentation by Heine Toftegaard (NPRA) and Siri Hustad (NPRA): New technologies NPRA would like to share on Confluence.

16:45 Demonstration of Options: Step by step walk through of actions required to do option 2 as the primary option. Outline options 1 and 3. Consortium to provide costs for each option.



Barriers to adoption of Confluence! Identify and discuss the barriers to implementation and options for moving forwards. Maybe use a 'World Café' concept to examine each step in each option and identify barriers. **Aim**: to let NRAs understand exactly what is involved and identify any barriers to adopting each option.

World Café: discuss options in groups…



Facilitated by Consortium team

18:00 Close

Day 2

Session 3 – in-person

09:00 Routes to Implementation – how new technologies have been implemented

- **PAS2161 – Shift to the new DfT (UK) condition data collection and assessment regime.** Drivers for change? ***TRL. – Alex Wright.***

PAS2161: PAS2161 provides the requirements for the collection, codification and reporting of road condition monitoring data for national reporting. The PAS does require the use of a specific type of technology for the collection of RCM data, but categorises various types of technology that can be deployed for the collection of RCM data.

not

Proposed presentations:

- Remote condition monitoring on Swiss National Road pavements - ***ASTRA – Federico Irali***
- Netherlands presentation on bridges - ***SHMnext – presented by: TUD Yuguang Yang***

Discuss and agree subjects for discussion in Session 4. ***Facilitated by Yuguang Yang***

10:15-10:30 Break

Session 4 – in-person

11:00 Process of Implementation: How does INFRACOMS help the NRA to get from learning about a new technology, to implementing it? ***Interactive session.***

Possibilities for discussion:

- Why was a technology developed? What are the drivers? How new technologies are driven by politics or technology. Understand the background and implementation journey.
- Delve deeper into creating a Technology Roadmap? Discuss how TRL assessed different data collection methods for DfT in the above example and how they fit to the INFRACOMS framework?
- Possibly use a technology provider as a resource to develop a roadmap?
- How to ingest new technology data into a RAMS and how it can be visualised. Use the TRL iROADS as an example, i.e. TRL work in Malta?

Facilitated by Consortium team

Session 5 – in-person

12:15 Revisit Session 2 from Day 1: Benefits and barriers to each option.

Plenary discussion session that asks whether NRAs would now be interested in adopting infracoms, in the light of the sessions above and the work discussed the previous afternoon?

Decisions on the way forwards. Funding, moderation, updating, motivating NRAs to take part.

Facilitated by Consortium team

13:00 Lunch

14:00 Close

Annex B: Final Event participant list

In-person participants

Name		**Organisation**
Per	Antvorskov	Vejdirektoratet (Danish Road Directorate)
Naida	Muirhead	CEDR – Conference of European Directors of Roads
Siri	Hustad	Statens Vegvesen (Norwegian Public Roads Administration)
Arjen	van Maaren	Rijkswaterstaat – Netherlands Ministry of Works
Susanna	Suomela	Väylävirasto - (Finnish Transport Infrastructure Agency)
Timo	Nuttens	AWV – (Flemish Agency for Roads and Traffic)
Federico	Irali	FEDRO (Swiss Federal Road Office)
Heine	Toftegaard	Statens Vegvesen
Marit	Due	Statens Vegvesen
Gordana	Petkovic	Statens Vegvesen
Ghita	Berg	Vejdirektoratet
Alex	Wright	TRL
Robin	Workman	TRL
Kevin	McPherson	TRL
Ali	Yeganeh	BRRC
Simon	Fjendbo	DTI
Anna	Arvidsson	VTI
Mogens	Saberi	COWI
Yuguang	Yang	TU Delft

Online participants

Name		**Organisation**
Dimitros	Papastergiou	FEDRO
Callum	Brown	National Highways
Fergal	Cahill	Transport Infrastructure Ireland (TII)
Hamid	Foroughi	TII
Tony	Williams	TII
PJ	Hourigan	TII
Gerard	O'Dea	TII
Stephen	Smyth	TII
Simon	Alvey	TII
Andrej	Anzlin	ZAG

CEDR Contractor Report 2025-02

Final Programme Report from CEDR Research Programme Call 2021 Remote Condition Monitoring of Physical Road Assets

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des Directeurs des Routes

Conference of European
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