CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

INFRACOMS
Innovative and Future-proof Road Asset Condition Monitoring Systems

Roadmap implementation report & Roadmap to adopt remote monitoring technologies

Deliverable D5.2 / D5.3

March 2024

TRL THE FUTURE OF TRANSPORT
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Belgian Road Research Centre
Together for sustainable roads
TU Delft
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Innovative & Future-proof Road Asset Condition Monitoring Systems

Report D5.2/D5.3

Final Version 1.0

Roadmap implementation report
and
Roadmap to adopt remote monitoring technologies

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Table of Contents

List of Figures

Abbreviations

Abbreviation	Definition
ASCE	American Society of Civil Engineers
CEDR	Conference of European Directors of Roads
DRD	Danish Roads Directorate
FHWA	Federal Highways Administration (US)
INFRACOMS	Innovative & Future-proof Road Asset Condition Monitoring Systems
NH	National Highways (UK)
NPRA	Norwegian Public Roads Administration (NO)
NRA	National Road Authority
RAMS	Road Asset Management System
TII	Transport Infrastructure Ireland (IR)
WP	Work Package

Executive Summary

INFRACOMS is a project under the CEDR Transnational Road Research Programme Call 2022 (June 2022 – May 2024) that aims to understand current and emerging techniques for remote asset condition monitoring and data collection to enable European National Road Authorities (NRAs) to strategically implement innovative technologies and approaches as standard practice. The project focuses specifically on two main types of assets: road pavements and bridges.

Previous INFRACOMS work packages have identified the priorities and needs of NRAs for the management of carriageway and bridge assets, in terms of their approaches to data collection and monitoring. The project has developed an appraisal methodology and toolkit for the evaluation of individual remote pavement and bridge condition monitoring technologies for potential use in NRAs and has conducted several case studies describing the actual implementation of these technologies. These appraisals and case studies were included in an Appraisal Toolkit implemented as part of the project as an on-line tool.

This report presents the outcomes of INFRACOMS WP5. WP5 aims to develop a methodology and toolkit for NRAs to guide them in the stages of work required to integrate new technologies into their asset management processes. This includes an organisational self-assessment tool to help NRAs understand their strengths and weaknesses around various aspects of best-practice in innovation. Using the results of their self-assessment, NRAs should be able to develop an **organisational roadmap** to help them improve in appropriate areas. A further aim of WP5 was to develop a framework for a technology roadmap, which would help NRAs identify the key technological components that would need to be included when developing a plan of action for introducing or implementing a specific technology for a particular use case. Note that the INFRACOMS proposal used the term “technology roadmap” for implementation planning, in this report the term **implementation plan** has been adopted.

The previously published D5.1 Self-Assessment Methodology Report describes the self-assessment methodology and tool for assessing the NRA’s innovation capability as an organisation. The report is accompanied by a self-assessment spreadsheet tool. The work presented in this report describes experience gained piloting the methodology with two NRAs, and the refinements identified through this process.

This report also describes the work undertaken to develop the framework for a technology implementation plan. The key elements of the implementation plan include: Risk management, cost-benefit analysis, legal/regulatory aspects, policy/standards, safety, environment, procurement, organisational capacity and digitalisation. The report describes the application of the framework and feedback provided by NRAs with whom the project has worked. This includes feedback and lessons learnt from an INFRACOMS workshop held in Copenhagen in March 2024, which aimed to train NRAs in the use of the methodology and tool, apply it to sample use cases, and establish any recommendations for refinements to the framework.

1. Introduction

1.1 The INFRACOMS project

The application of consistent, reliable information has been a key component of highway asset management for over 40 years. The information and the tools to help collect, interpret and apply data have continuously evolved during that time. Technologies with the potential to support asset management include remote sensing, intelligent infrastructure monitoring, crowdsourcing, data analytics and visualisation. In this report they are collectively referred to as 'Remote Monitoring Technologies'. However, National Road Authorities (NRAs) in Europe are not yet fully exploiting their potential in the highway environment to better understand highway assets and to improve reactive and proactive asset management decisions.

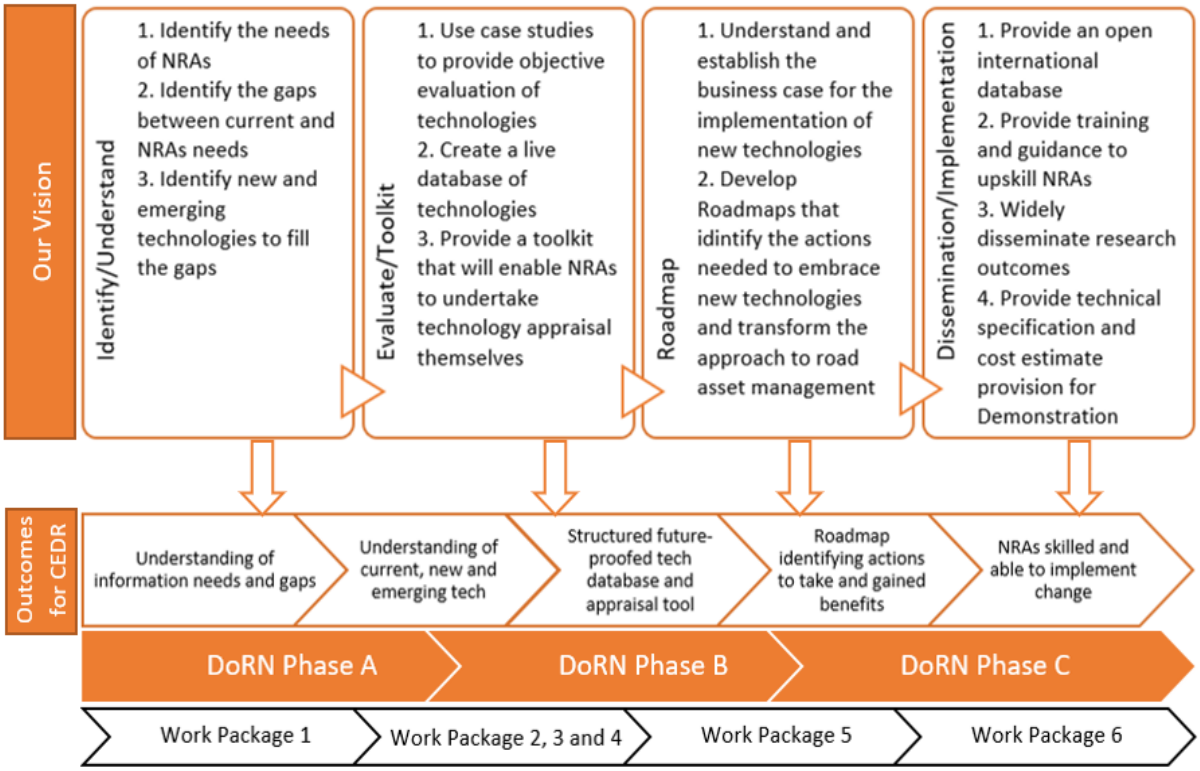

Figure 1. Vision and outcomes of INFRACOMS.

INFRACOMS aims to equip NRAs with the ability to better leverage the technological evolution in data and monitoring. Figure 1 summarises the approach being taken in this project. INFRACOMS is investigating the capabilities and benefits of new technologies for understanding the performance of highway assets. INFRACOMS is establishing a database of these technologies and a toolkit to appraise them, which aims to help NRAs assess the costs, benefits and limitations of applying the technologies in their own environments. INFRACOMS will also provide a roadmap to provide strategy and guidance for NRAs to improve their business processes for more effective assessment and implementation of new technologies.

1.2 Overview of INFRACOMS Work Packages

This report (D5.2/D5.3 – Roadmap implementation report & Roadmap to adopt remote monitoring technologies) has been prepared under Work Package 5 of the INFRACOMS project. Figure 2 shows the relationship of the INFRACOMS work packages, tasks and deliverables with respect to WP5.

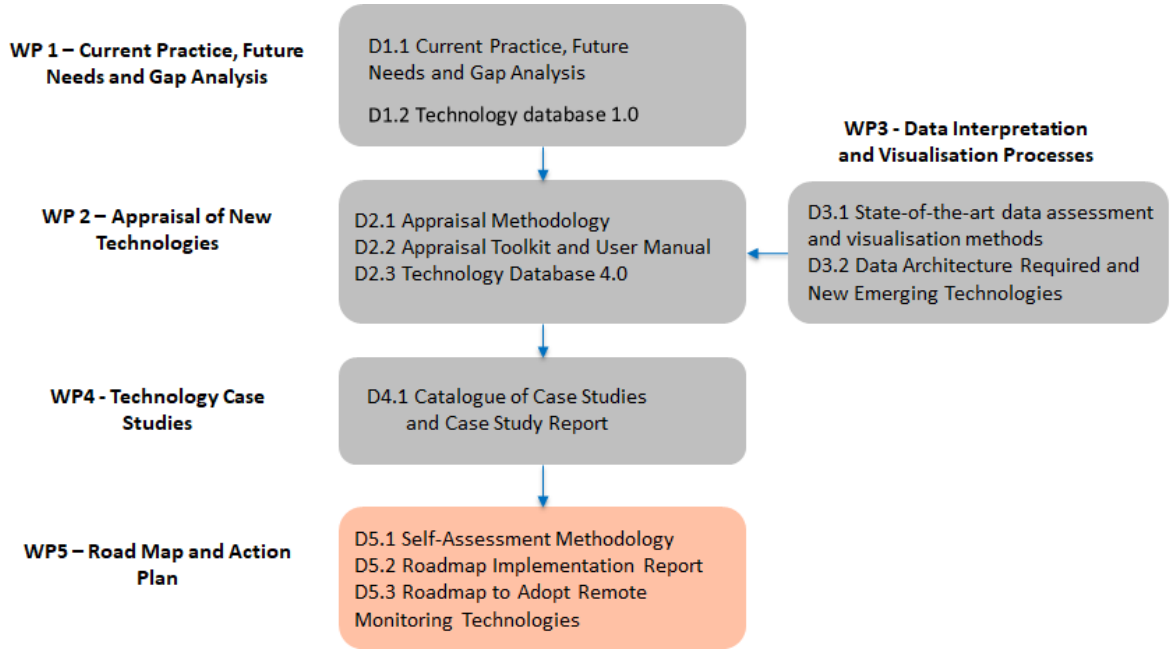

Figure 2. Relationship of WP 5 to other Work Packages, Tasks and Deliverables.

WP1 report D1.1 on Current Practice, Future Needs and Gap Analysis identified the priorities and needs of NRAs for the management of carriageway and bridge assets in terms of their approach to data collection and monitoring. It identified gaps in data, challenges in collecting data, and challenges in application of data. It also identified technologies that can address those gaps and challenges. WP1 also produced D1.2 - Technology Database 1.0. This contained a list of remote condition monitoring technologies and mapped them against the current and future asset management needs / gaps identified in the consultation.

WP2 combined the outputs from WP1 with the outcomes of a review of appraisal methodologies, and a workshop with NRAs, to devise an overall methodology for appraising the technology, on the basis of technology use cases. The outcomes of this work were presented in INFRACOMS deliverable D2.1. An Appraisal Toolkit and User Manual were also implemented as a wiki solution using the Confluence platform (D2.2). The Appraisal Toolkit incorporates the Technology Database 4.0 which includes appraisals of around 20 technologies in the context of specific use cases for those technologies (D2.3).

WP3 reviewed and evaluated the data assessment and visualization methods provided by the types of technologies contained within the Technology Database. It discussed the types of data that may be provided by a technology to describe the asset and its condition and produced a methodology for assessing the methods provided by the technology for data analysis and representation (D3.1). It also produced a methodology for assessing the data architectures of NRAs and an appraisal scoring process to evaluate the potential of technologies to support practical decision-making (D3.2). These methodologies were incorporated into the overall appraisal methodology of WP2.

WP4 reported on a set of real-world case studies for the most promising technologies identified using the appraisal methodology. It developed a semi-formal approach to undertaking detailed assessment of selected technologies, including costs and benefits associated with their implementation, and practical issues around implementation of the technologies encountered by individual NRAs. The case studies included mobile imaging, aerial satellite spectroscopy, a virtual bridge inspection platform, a wireless acoustic emission measurement system, and bridge weigh-In-motion technology.

This report presents the outcomes of WP5. WP5 aims to develop a methodology and toolkit for NRAs to guide them in the stages of work required to integrate new technologies into their asset management processes. This includes an organisational self-assessment tool to help NRAs understand their strengths and weaknesses around various aspects of best-practice in innovation. Using the results of their self-assessment, NRAs should be able to develop an **organisational roadmap** to help them improve in appropriate areas. A further aim of WP5 was to develop a framework for a **technology implementation plan** (or "roadmap", which was the term used in the INFRACOMS proposal). This will help NRAs identify the key technological components that would need to be included when developing a plan of action for introducing or implementing a specific technology that has already been appraised under the INFRACOMS appraisal methodology.

1.3 Scope of this Report (D5.2/D5.3)

WP5 included several tasks as shown in Figure 3. Tasks 5.1 and 5.3 were covered in Deliverable D5.1. which describes the INFRACOMS organisational Self-Assessment Methodology and Self-Assessment Tool. Chapter 2 of this current Deliverable (D5.2 / D5.3) presents experience gained piloting the methodology and self-assessment tool with two NRAs. Chapter 0 describes the development of the framework for a technology roadmap. Chapter 3.3 describes the application of that framework (by the same two NRAs that participated in piloting the organisational roadmap), and incorporates feedback from a workshop (Workshop 4) held in Copenhagen in March 2024, at which training was given (and hence experience gained) on the appraisal toolkit and frameworks.

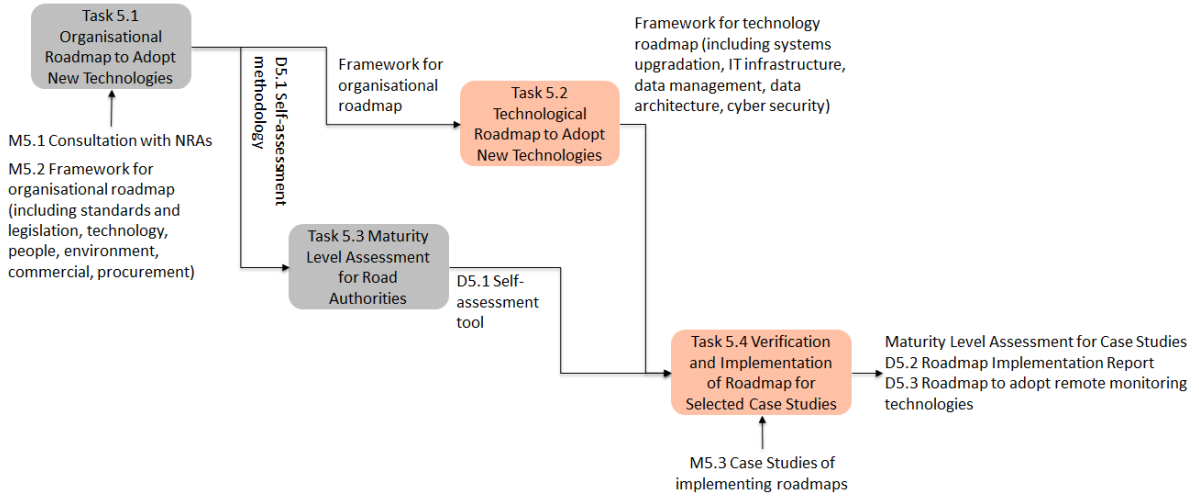

Figure 3. Scope of Deliverable D5.2/D5.3

2. Organisational Assessment

2.1 Self-Assessment Methodology and Tool

Deliverable D5.1 has presented the INFRACOMS self-assessment methodology. The methodology addresses the four INFRACOMS toolkit workstreams of Strategy, Planning, Development and Implementation. The self-assessment methodology was implemented as a self-assessment tool, based upon a questionnaire that is completed by NRA to establish their current and future status, capability and ambitions with regards to innovation and technology, in the context of these workstreams.

The self-assessment tool is structured around a series of statements, with which NRA representatives can “Strongly Agree”, “Agree”, “Disagree”, “Strongly Disagree”, or “Don’t Know”. Figure 4 shows an extract from the Self-Assessment Tool completed for a fictional NRA in the Strategy workstream. Figure 5 shows a radar diagram of the results of this organisational assessment. The radar diagram visualises the comparison between current practice at the organisation and good/best practice in each workstream (in which the NRA would “Strongly Agree” with each statement). The following section discusses the experience gained piloting the tool described in D5.1 with two NRAs.

STRATEGY. Identification of the NEEDS and OPPORTUNITIES

S1	Remote condition monitoring for asset management is clearly highlighted as a key area for innovation in the organisation’s strategic plan.	3 - Agree
S2	The organisation has a clear commitment to fostering a culture of innovation.	1 - Strongly Disagree
S3	Responsibilities for innovation within the organisation are clear.	2 - Disagree
S4	The organisation has a clear commitment to working with its supply chain and with wider industry to innovate to address emerging needs.	3 - Agree
S5	The organisation is open to considering innovative ways of funding technology implementations.	4 - Strongly Agree
S6	The organisation’s human resource management policies and procedures actively encourage a culture of innovation (e.g. through a mix of measures including staff recruitment, staff evaluation, staff retention, incentives, training programmes, mentoring, and change management).	4 - Strongly Agree

Figure 4. Sample Questions from the Self-Assessment Tool

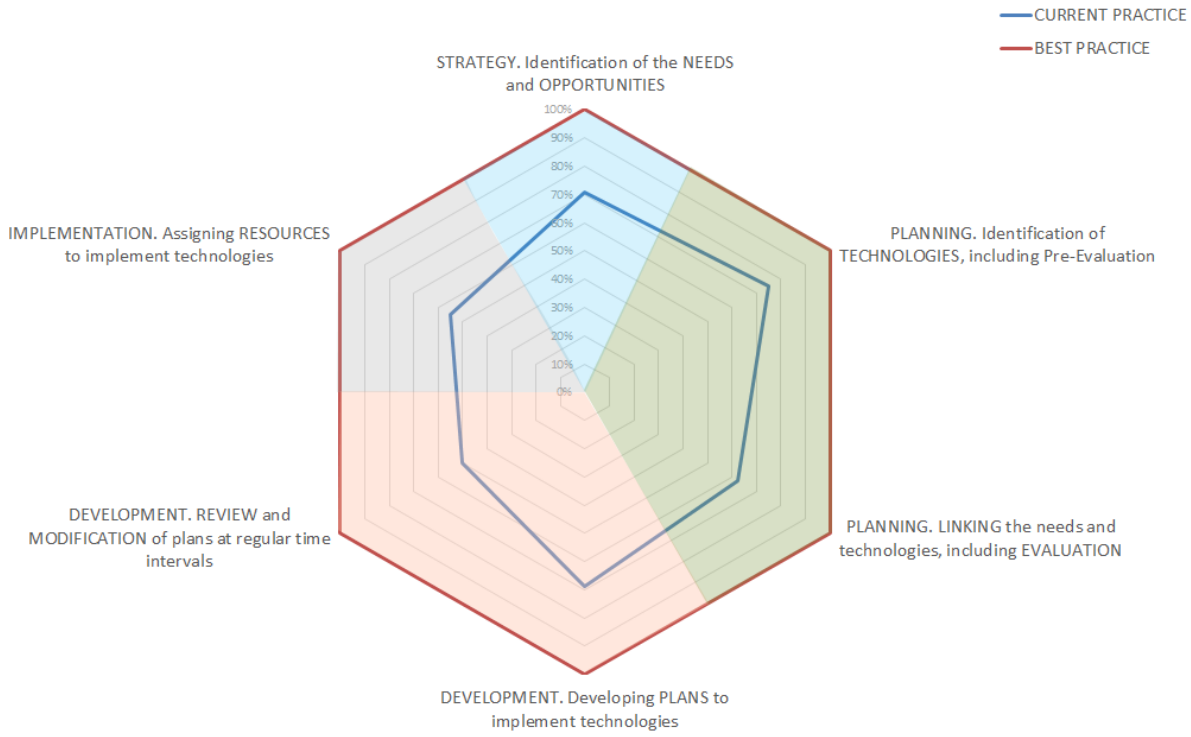

Figure 5. Radar Diagram of Organisational Assessment

2.2 Application of the Assessment Methodology and Tool

Two NRAs agreed to pilot the assessment tool as part of a self-assessment exercise. These were the Norwegian Public Roads Administration (NPRA) and National Highways in the UK (NH).

The assessment tool is primarily intended to identify the strengths and weaknesses of an organisation. Neither pilot organisation wished to share the specific *results* of their self-assessment in this report. Nevertheless, they agreed to share their feedback on the questionnaire itself and the process of applying it.

2.2.1 Norwegian Public Roads Administration (NPRA)

A stakeholder meeting was held on January 25th 2024 with representatives from NPRA, in which INFRACOMS consultants walked through the questionnaire with 10 persons from various branches of the NPRA. Key feedback and takeaways from the session with the NPRA were as follows:

a) Several differences of opinion between NPRA representatives indicated that there are different perceptions within the organisation of what is working well, and what is not working so well. The fact that the application of the questionnaire highlighted those different perceptions was regarded as a plus point, encouraging discussion about possible actions to improve messaging.

b) Some NRAs have several thousand employees. The size and composition of the organisation may impact the way in which the questionnaire is conducted. Therefore, there may be a need to conduct the assessment at the divisional level, for example, with the results from each division collated and compared to identify and assess different perceptions across the organisation, for later analysis and discussion by senior management.

c) The guidance for the tool should advise on the pros and cons of involving people from different parts of the organisation into the discussion. Some parts of the questionnaire may be more appropriate for a wider audience across different career levels, for example, while others may be more appropriate for senior executives only, or for human resources personnel.

d) Discussion highlighted some practices that were being followed in one part of the organisation but not in others. This may indicate opportunities to improve communication within the organisation or highlight challenges in scaling up innovations from one part of the organisation into another.

e) Some questions in the questionnaire could benefit from introductory text as to the purpose of the question, explaining why it may be important or why it is considered best practice.

f) Some questions were slightly ambiguous or could be worded slightly better.

g) A notes column should be included at the end of each question to capture notes of any discussions on justification for the response and/or differences of opinion obtained in the session.

h) A preamble should be included to encourage frank discussion and feedback from members. The preamble should discuss potentially different drivers for innovation in public sector organisations versus private sector organisations.

i) At the end of the questionnaire, visualisation should highlight weak areas and there should be some guidance as to how to use the results from the questionnaire to develop an` organisational action plan.

INFRACOMS received the following feedback from NPRA on 1st March 2023:

> *"The tool is interesting and can certainly be useful for the Norwegian Public Roads Administration. It can help us to see the use of new technology in the context of how "mature" the organisation is for new opportunities. For example, work processes, expertise, organisational adaptation and ownership of data and strategic decisions in relation to what we should have in-house and what should be outsourced. The Norwegian Public Roads Administration aims to adopt new technology, but this is about much more than the "new technology". The roadmap helps us systematically put these important issues on the agenda. For us, the roadmap can work if we gather people involved at different levels and within different areas of the organisation and use the tool for a common reflection and discussion. We can then together assess where we are and what we should work towards. As I see it, the tool should be used over time, we do an evaluation that is repeated after we have worked on the topics that we agree should have focus.*
>
> *The result of the evaluation/use of the tool should be followed up by a discussion about what is required of the organisations to move forward? What do we need to move on, get better/ lift the organisation? What opportunities do we have to manage this? Then we need to set up a plan of what we will do until the next evaluation/use of the tool. Then we can use the tool again and together evaluate / "measure" whether we think we have moved in the right direction.*
>
> *Challenges in the organisation. It is unclear who is "responsible" for innovation and improvement. Who should use the tool and implement the necessary agreed activities? We work with development and new technology in many parts of the organisation. Individuals and the environment work with "pieces in the big picture". It must be clarified who has overall responsibility for following up/coordinating the use of individual technologies, ensure that we work systematically with new, enabling technologies in relation to more "traditional subjects", strategies and organisational adaptations".*

2.2.2 National Highways (UK)

National Highways (NH) has committed to using the questionnaire to conduct its own self-assessment, however they did not wish INFRACOMS consultants to be present during that assessment. NH has agreed to provide feedback to INFRACOMS on their experience of using the tool, but such feedback had not been received at the time of writing this report.

2.3 Updated Assessment Questionnaire and Tool

As a result of the pilot applications of the tool in the two organisations described above, changes were made to the tool:

- A preamble was added to incorporate descriptions and suggestions on the purpose of the tool. This includes: suggestions for the format of workshops; guidance on attendees and their responsibilities; the conduct of the workshop; preparation of an action plan; and follow-up meetings to track progress on the action plan.
- Some statements in the tool were reworded to make them more clear, and a notes column was added to capture discussions during workshops.
- An additional summary chart was devised and included in the toolkit. The chart aims to better visualise the weak and strong areas in an organisation, and thus facilitate internal discussions. It shows Basic, Proficient and Advanced maturity levels - see Figure 6.

The final version of the tool was published on the INFRACOMS website and added to the INFRACOMS Knowledge Base and Appraisal Toolkit.

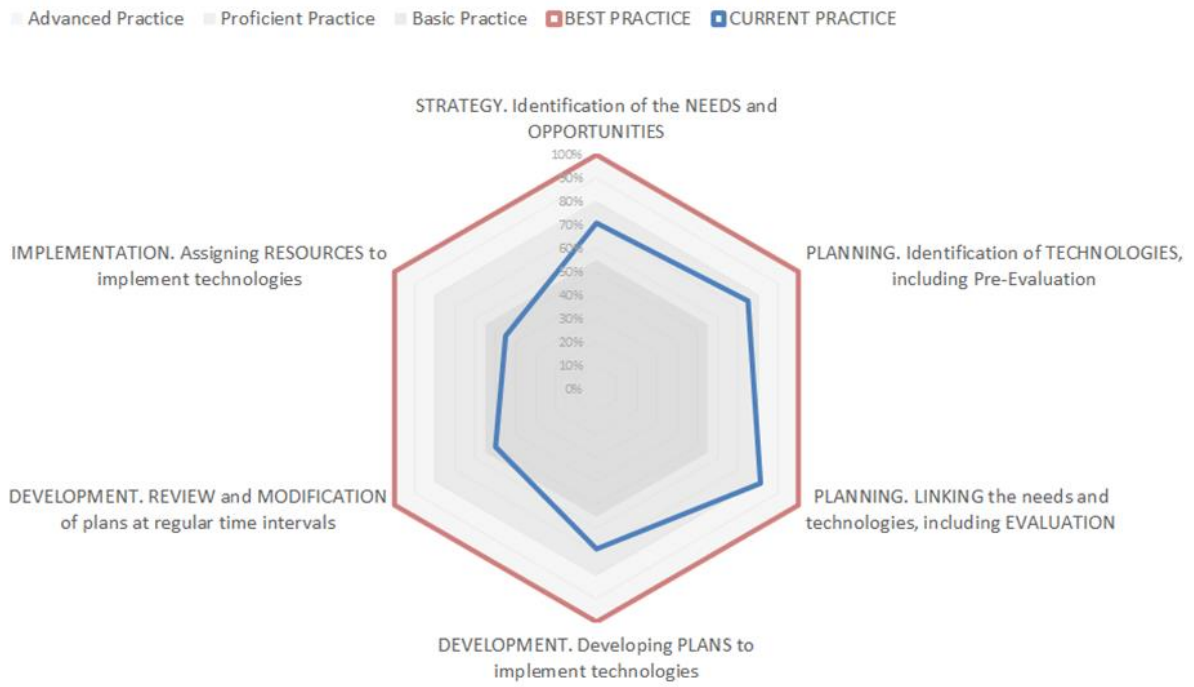

Figure 6. Radar Diagram of Organisational Assessment (updated)

3. Framework for a Technological Implementation Plan

Once a technology has been appraised as suitable for implementation in a road organisation, then it is necessary to produce a plan to implement that technology within its proposed application (use case). Note that, although the INFRACOMS proposal used the term 'roadmap', we have adopted the term 'implementation plan' in this report. A 'roadmap' provides a strategic overview or direction, while an 'implementation plan' is more time-bound with specific tasks and resource allocations, and outlines the practical steps required for NRAs to implement a particular technology. The objective of this part of WP5 was to establish a framework that could be used as a foundation by NRAs when developing their own technological implementation plans.

3.1 Background and literature

Background research and a review of literature, including innovation policies and procedures from a number of transport organisations, was undertaken to identify existing approaches taken to the development of implementation plans.

An implementation plan should recognise the importance of aligning with the organisation's strategic objectives, lifecycle planning, stakeholder engagement, and the adoption of technologies that provide tangible improvements in infrastructure management. The plan should facilitate effective communication among stakeholders, guide change management, and ensure that technological investments contribute efficiently to the organisation's mission—e.g. enhancing safety, sustainability, and service delivery across infrastructure systems (Reda Taha, Ayyub, & et al, 2021).

The TII 'Guidelines for the Implementation of Innovation' (Transport Infrastructure Ireland, 2020) are a good example of how innovations can be implemented in a logical and structured way to implement a new technology. That document is based on a refined Technology Readiness Level scale, where the technology is subjected to a Risk Assessment and Cost-Benefit Analysis at each TRL stage before it can be promoted to the next stage. TII's risk categories include operational, political, financial, reputational, digital and safety.

The American Society of Civil Engineers (ASCE) and the Federal Highway Administration (FHWA) also provides a framework to guide infrastructure advancements. ASCE's Infrastructure Report Card (American Society of Civil Engineers (ASCE), 2017) assesses current infrastructure conditions and assigns grades using criteria such as condition, future funding, public safety, resilience, and innovation (including what new innovative techniques, materials, technologies, and delivery methods are being used to improve the infrastructure). Many states in the US use the ASCE report card criteria to 'score' their infrastructure annually.

The FHWA's Pavement Management Roadmap (Federal Highways Administration (FHWA), 2022) delineates the future vision and strategies for pavement management, and identifies advancements in tools, methodologies and technologies as key improvement areas. Suggested actions include supporting the expanded use of performance measures, developing and deploying content to support workforce development, development of automated approaches for processing and analysing data, establishing deployment strategies for use of crowdsourced data, documenting precision/bias statements, and using new technology in concert with traditional data collection.

The above examples serve to demonstrate that there is a relationship between organisational goals (as considered in the organisational roadmap described in section 2), and the technological implementation plan. The organisational roadmap is concerned with innovation management as a process. It identifies best practice in strategic planning, identification, evaluation, and implementation

of new technologies, and encourages the organisation to consider the steps it can take to improve the ways in which it manages these. The technological implementation plan, on the other hand, relates to detailed steps necessary to implement a particular technology. However, the technological implementation plan must be developed and delivered in the context of the organisation capability and constraints. Hence, elements of a technological implementation plan will be influenced or constrained by the organisational framework within which it sits. For example, at the organisational level, there should be a clear statement of the direction of the organisation with regards to its key imperatives and technological priorities, which should help to justify the implementation of a particular technology. Similarly, a mature organisation committed to innovation may have dedicated policies or procedures to establish a common approach to identification of stakeholders, change management, risk management, training and development, and measurement and celebration of success.

3.2 Framework for an Implementation Plan

Building on the above review, INFRACOMS has identified that the key elements which must be addressed by a technological implementation plan (for implementing a new technology within a specific use case) include: risk management; cost-benefit analysis; legal/regulatory; policy/standards; safety; environment; procurement; organisational capacity; and digital - as shown in Figure 7. Each of these elements is discussed in the following sections.

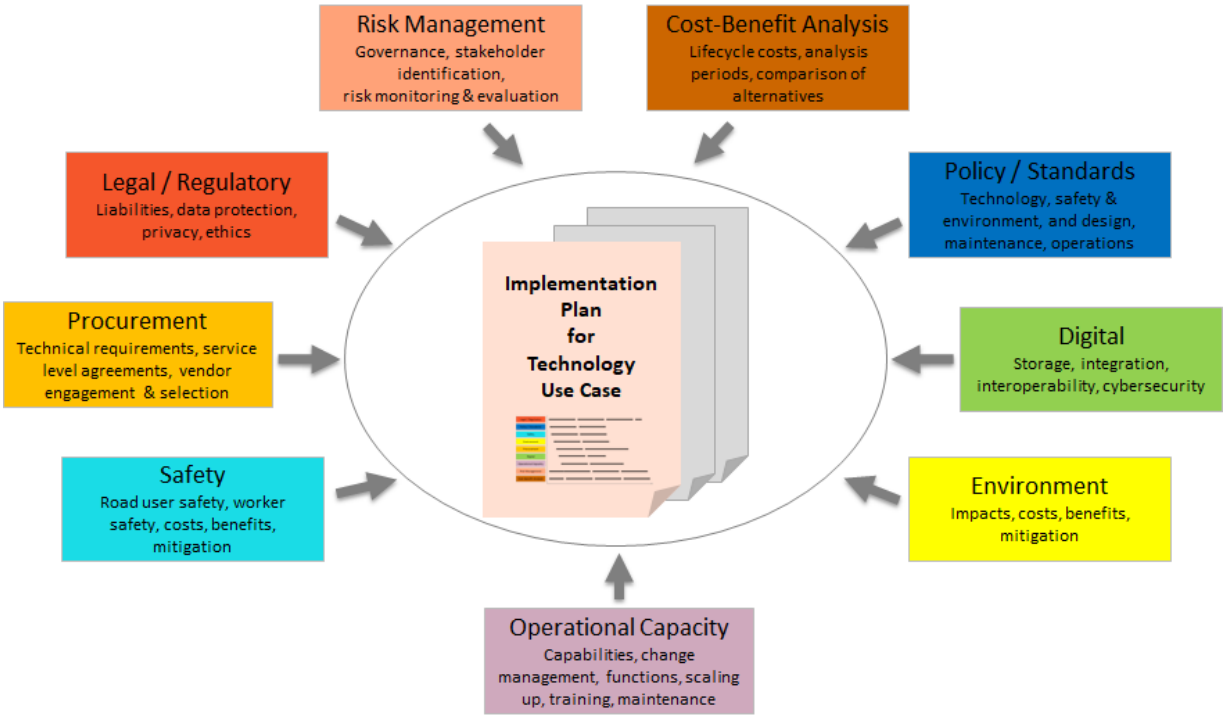

Figure 7. Framework for Creation of an Implementation Plan for a Technology Use Case

3.2.1 Risk Management

There will be risks associated with any new technology. It is essential to consider these risks and how they are being exposed by the new technology. Which stakeholders need to be consulted, both internal and external? What are the highest priorities? How can risks be managed and mitigated? What will the impact be on the organisation?

Areas that the NRA should consider when developing their implementation plan should include:

- ***Practical risk:*** What are the practical risks to the organisation of implementing the new technology?
- ***Reputational risk:*** Is there anything related to the new technology that could damage the reputation of the organisation?
- ***Financial risk:*** Are there financial risks, perhaps through failure of the technology?
- ***Monitor and review risks:*** The organisation should continue to review and monitor risks throughout the planning for implementation of the technology.

3.2.2 Cost-Benefit Analysis

The procedures for analysis of costs and benefits of a technology for a particular use case will depend on the NRA's existing processes. As highlighted in INFRACOMS Deliverable D2.1, most analyses include comparison of alternatives, determination of analysis periods and activity timing for maintenance and rehabilitation, determination of cost factors and computation of life-cycle costs of the technology.

However, many new technologies may not have robust information available on life-cycle costs. This may be a result of lack of experience operating the technology - for example, there may be operational experience with a sensor in a particular environment for five years, but the sensor could be estimated to last for 20 or 30 years. Therefore, some assumptions will need to be made and clearly stated when carrying out a review of costs and benefits for a new technology.

Areas that the NRA should consider when developing their implementation plan should include:

- ***Whole-life costs:*** Consider the lifetime costs of the technology, e.g. how long will it last, how can it be replaced? (e.g. an embedded sensor)
- ***Costs and benefits:*** What are the costs and benefits over the life of the technology or the asset?
- ***Financial rules and regulations:*** Does the NRA need to consider financial rules or regulations, will they affect implementation?
- ***Monitor and review cost-benefit:*** How can the costs and benefits be regularly reviewed, throughout implementation planning as well as throughout operation?

3.2.3 Legal / Regulatory

New technologies may not fall within existing legislation, or the legislation may not yet be established to encompass the technology. Transport-relevant examples could be drones or electric scooters, where the technology was implemented before legislation was fully developed. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review existing laws:*** Will it be necessary to review legislation for the implementation and operation of the technology (e.g. drone use)? Are there any legal or regulatory gaps or barriers?

- ***Ethics review:*** Are there any ethical considerations for this technology?
- ***Propose new legislation:*** Will it be necessary/feasible to propose new legislation and how long would that take?
- ***Define liability boundaries:*** Who will be liable?
- ***Develop legal framework:*** Will it be necessary to develop a legal framework for the technology?

3.2.4 Policy / Standards

Any new innovation should be aligned to the policy and standards of the NRA in which the technology is to be implemented. Policy helps organisations and their stakeholders understand the use to which technology will be put, and the boundaries within which the technology will operate. Standards are required for consistency of use and application of the technology for its specific purpose. Any new technology is likely to require update of existing policies and/or standards. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review policy:*** Review existing policies to confirm that the new technology will be compliant with overarching policies and develop or update as necessary.
- **Review technical standards:** Review existing technical standards for the technology including those with respect to safety, environment, technology etc. to ensure safe and sustainable operation.
- **Review organisational standards:** Review the standards or procedures in the organisation that may need to be updated with respect to the use of the technology for decision-making, especially if it is replacing an existing established process.

3.2.5 Procurement

It is important to consider any impacts that there could be on the public procurement process, whether it will comply with EU regulations and whether any changes would be needed to accommodate the technology. Issues may include the production of terms of reference including specifications around supply of data and integration with existing IT systems, service level agreements, how to deal with a procurement process in which there may only be 1 potential supplier, the rules around engagement with suppliers during development of specifications, and incorporation of enhanced data or services or additional requirements into ongoing contracts. Areas that the NRA should consider when developing their implementation plan should include:

- ***Establish conditions for specification:*** Will procurement comply with existing regulations?
- ***Decide on process:*** Decide how the new technology will be procured. There may be established routes for using new technology - including pilots and trials. However, a risk associated with pilots is that they may be insufficient in scope to fully establish the capability of the technology. This can delay or restrict the transition to full implementation.
- ***Scope of services:*** Produce a scope of services for the new technology. It may be necessary to liaise with the provider.
- ***Procurement Indices***: The development and use of indices to encourage innovation around areas such as efficiency or circular economy.
- ***Procurement rules:*** In the light of the above, decide on the procurement rules necessary for this technology and tender process.

3.2.6 Digital

The new technology may not be fully compatible with the existing asset management and IT architecture of an organisation. It is unlikely that existing systems can be changed to suit a single new technology, so the organisation will need to consider how a new technology can be accommodated within the existing systems. Also, cyber-security represents a significant risk to many organisations. It may be difficult to accurately predict the risk of cyber-security, but the organisation will need to consider what security enhancements to make for protection. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review existing systems:*** What RAMS or asset database systems are in place.
- ***Compatibility and integration:*** Review the compatibility of the existing systems to accept the new technology, how would they interact, are the data compatible etc.
- ***Data storage:*** What are the data storage requirements? If very high, what resources will be required? Does the NRA require the results only, or do they need the raw data as well?
- ***Data sharing:*** What format is the data in? How will it be shared, and with whom?
- ***Planned upgrades:*** When/how often does the software need to be updated? How will these be planned and accommodated across the lifecycle of the technology and the systems into which the data is to be loaded?
- ***Assess cyber-security concerns:*** Are there any potential concerns/risks over the new technology*?* What actions will be needed across the lifecycle to manage these?
- ***Review cyber-security standards:*** What are the existing standards and how do they relate to the new technology?

3.2.7 Safety

The safety of the new technology must also be considered. This would include safety of the user and the organisation's staff (if different), as well as safety of road users and the general public. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review safety risks:*** What are the safety risks? Are these likely to change over time?
- ***Cost*-Benefit analysis**: How will be safety impact of the new technology ne included in cost-benefit analyses?
- ***Design safety review:*** What procedures does the NRA have in place to check safety of new technologies? Will new procedures need to be implemented? What is the process and timescale for this?
- ***Safety improvements:*** Are any safety improvements necessary before full implementation?

3.2.8 Environment

The environmental impact of the new technology must also be considered, and plans made to mitigate potential impacts to ensure sustainable and responsible deployment. This might include energy consumption, resource use, generation of waste, data centre energy consumption, and transportation impacts. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review environmental risks:*** What are the current environmental risks? Will these change over time as new standards and requirements are put in place?
- ***Cost-Benefit analysis***: How is the environmental impact of the new technology included in cost-benefit analysis?

- ***Environmental review:*** What procedures does the NRA have in place to review environmental impacts and mitigations for new technologies? Do new procedures need to be designed and implemented?

3.2.9 Operational Capacity

Every organisation will have a different capacity to implement new technologies, both from an institutional and a capacity perspective. The organisation needs to consider their organisational capacity to implement new technologies. Areas that the NRA should consider when developing their implementation plan should include:

- ***Review current capability of the organisation:*** In general, does the organisation have the capacity to implement the new technology. There is strong link here to the organisational roadmapping activity.
- ***Identify functions***: What new/changed functions will the new technology bring (e.g. in terms staff resources, support etc)?
- ***Training:*** What training may be required, and what should be the outcomes?
- ***Deployment:*** How/when will the new technology be deployed?
- ***Maintenance requirements:*** What might be the maintenance requirements for the technology?
- ***Capacity building:*** In the light of the above, what capacity building will be necessary within the organisation to fully implement the new technology?
- ***Change Management:*** Is a Change Management Plan required, to prepare, communicate, and plan for any changes to the organisation?
- ***Scaling Up:*** With new technology there is often the risk of focussing on single focussed applications. Wider benefits, including proportional cost reductions, are achieved through scaling up and a switch to the use of new tools as “business as usual”. However, scaling up of technology is a major issue for many NRAs. Early planning for scaling up is useful and should form part of the implementation plan. A scaling-up plan may include many of the other elements such as piloting, assessment of resources, internal publication, and monitoring and evaluation of benefits.

3.3 Developing an Implementation Plan Using the Framework

Whilst the above sections discuss the nine elements separately, there is a need to consider how they interact when developing the implementation plan. For example, risk management can be seen to encompass many other elements. It often includes identification of stakeholder groups and may help dictate the priorities for development of the plan. If there is a particular risk identified, for example in the legal or regulatory element, then it will probably be important for that work to start early given that the entire plan may rest on resolution of any legal or regulatory issues. Therefore, the risk management element may be one of the first elements considered when developing the plan as it will highlight other key elements and help identify which of these should be prioritised. Similarly, standards development often involves many stakeholders and can take considerable time for development and review. Cost-benefit analysis will also likely encompass all other elements and will evolve with the implementation plan as the costs and benefits become fully understood.

Application of the framework will hence result in the development of an implementation plan for use of the technology. The plan will include a set of actions within each of the elements of the framework and would be programmed to accommodate any overlapping/interacting requirements, as depicted in Figure 8.

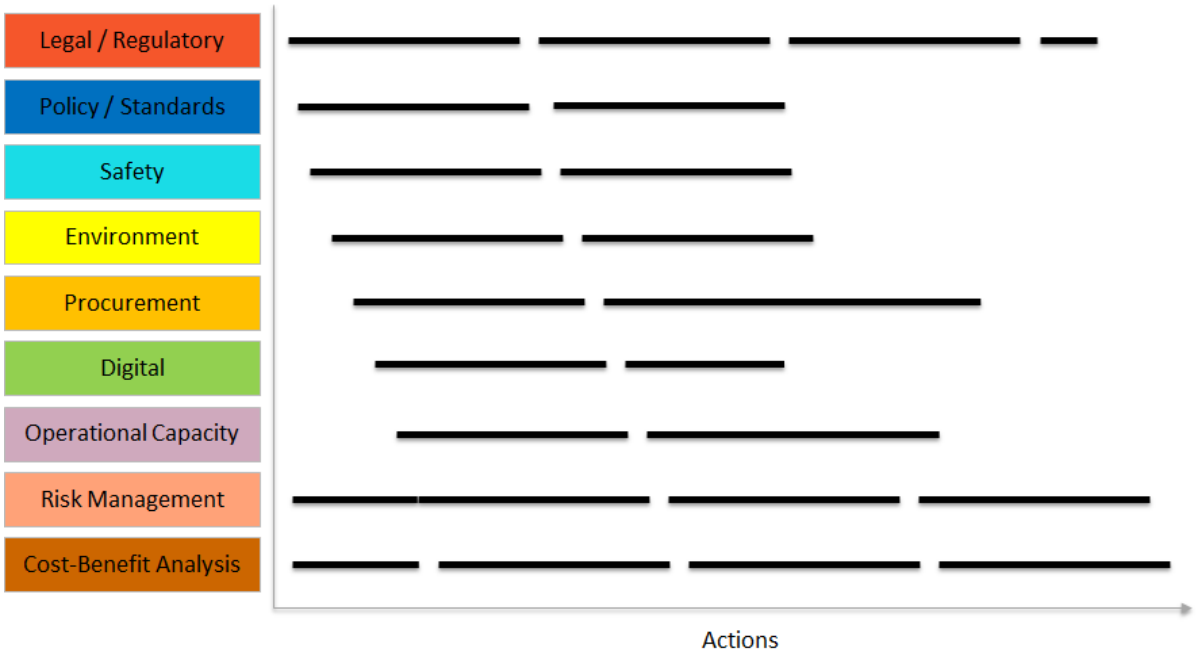

Figure 8. Implementation Plan for a Technology Use Case

The proponent of the new technology should be a key contributor/leader of the implementation plan. However, development of the plan would ideally be guided and supervised by a further member of the NRA bringing a wider organisational viewpoint. The introduction of the new technology should be delivered as a project, in the same way as other projects are managed in the NRA. By following the implementation plan, the project would consider the overall technological and strategic objectives and not be delivered as a standalone trial or pilot of new technology. Adopting the "standalone" route brings high risk of local (in the NRA) implementation and reduced integration into the NRAs systems and business processes. The plan should clearly articulate the goals and objectives for the innovation, identify the key stakeholders, facilitate the allocation and management of resources, establish budgetary control, and track expenditures.

The end result of the innovation project would be the deployment of the technology for its intended purpose. Lessons learned from the innovation would be documented and stored to give insights into the planning and deployment for future project. The costs and benefits of the innovation would continue to be monitored throughout the life of the technology, according to the NRAs' benefits monitoring framework.

3.4 Review with NRAs and updated Implementation Framework (within the toolkit)

To explore the use of the implementation framework, the framework was discussed in dedicated sessions held with two individual NRAs, and also presented in the Training Workshop held in Copenhagen in March 2024. These sessions enabled participants to interact with the framework (as hosted within the Confluence platform) and provide feedback. Appendix A of this report provides a summary of these sessions and the feedback received from the stakeholders.

As a result of this stakeholder engagement, some refinements were identified for the toolkit, to be implemented as part of the final stage of the INFRACOMS project. These refinements include:

- Additional guidance on use of the tool, in the form of flowcharts where possible, explaining the initial identification and pre-evlauation of the technology, prior to identifying and elaborating on use cases.
- Additional information on drop-down menus where useful.
- Addition of a short video explaining the purpose and key elements of the toolkit.
- Incorporation of the Technology Roadmap including the outputs from this Deliverable D5.2/5.3 into a Technology Appraisal.
- Addition of a page in the toolkit to accommodate research papers.

4. Summary and Conclusions

WP5 of the INFRACOMS project has built on the work undertaken in previous work packages, which have established a database of new technologies for understanding the performance of highway assets, and a toolkit to appraise them. WP5 has aimed to address wider organisation issues associated with the implementation of new technology, in particular the need for organisational roadmaps to help NRAs understand their general capability with respect to innovation, and the need for technological implementation plans to help NRAs understand the actions they need to take to implement specific examples of new technology.

Organisational Roadmaps: The development of organisational roadmaps began with a self-assessment methodology, enabling NRAs to gauge their current innovation capabilities and readiness to implement new technologies. The approach covers four main areas: Strategy, Planning, Development, and Implementation. By structuring the assessment around these areas, NRAs can evaluate their strengths and weaknesses in relation to best practice for innovation management. This process is crucial for identifying gaps in an organisation's ability to adopt new technologies and for fostering a culture of continuous improvement. Feedback from pilot assessments with NRAs has indicated that involving diverse organisational perspectives in the assessment process not only highlights different perceptions within the organisation but also pinpoints areas for internal communication and process improvements.

Technological Implementation Plans: The technological implementation plans focus on the practical aspects of implementing specific technologies within the existing asset management frameworks of NRAs for a specific use case. INFRACOMS has synthesized background research and literature to develop a comprehensive framework upon which to base these plans. The framework addresses critical elements such as risk management, cost-benefit analysis, legal/regulatory considerations, policy/standards alignment, safety, environmental impact, procurement, organisational capacity, digital integration, and operational scalability. This approach emphasizes the importance of a holistic review and strategic planning phase prior to the adoption of any new technology, ensuring that all potential risks and benefits are thoroughly analysed and aligned with the organisation's strategic objectives.

WP5 has integrated feedback from NRAs and lessons learned from workshops to identify refinements to the methodologies. These include practical guidance on overcoming common challenges, such as navigating regulatory landscapes, ensuring compatibility with existing IT systems, and managing change within the organisation. The project also highlighted the necessity of developing clear action plans for technology deployment, including training, maintenance requirements, and scaling strategies. These refinements will be built into the web-based tool that has been adopted as the host for the INFRACOMS toolkit.

5. References

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6. Appendix A – Experience gained with the Technological Implementation Framework

6.1 Norwegian Public Roads Administration (NPRA)

The NPRA provided the following feedback on the guidance provided in the technological implementation framework.

It is a great advantage for us to have such a tool. The Norwegian Public Roads Administration has been working on piloting new technology for several years, much of which has been tested. What we are weak at is evaluating, documenting and making available the results of piloting. The INFRACOMS methodology helps us to do this in a "standardized" way, which in turn will help us to be active in adopting new technology and perhaps avoid testing the same technology several times. We speak the same "language" and we understand results documented by, for example, testing.

Another area of improvement for us in the Norwegian Public Roads Administration is to make a plan for realisation, testing/piloting of new technology. The plan for deployment/scaling must be started at the same time as piloting is started. One must assume that the piloting is successful from the start, and thus ask oneself and work systematically on what is needed to scale up after a successful pilot has been completed. I think the tool that has been developed will help us with that when evaluating the individual technologies in relation to the paraments that have been set up. Furthermore, the organisational tool will also help us put new technology and technology adaptation into the context of strategy issues, organisational adaptations, expertise, business and needs that the organisation has in the short and long term.

What is a challenge is to define the needs we have in the short and long term, what challenges we have and then ask how new technology/new information we obtain should be incorporated into workflows and work processes. Furthermore, what expertise new technology will require of us and how this should also be viewed in the context of organisational adjustments.

The Norwegian Public Roads Administration as a public actor is subject to regulations related to public procurement. We must define and describe needs and functionality when acquiring technology. When we have the INFRACOMS tool, this will give us impulses and a concrete understanding of where the "technology front" lies and what is possible to request in a procurement process. This is an advantage.

6.2 National Highways (NH) of UK

A workshop was conducted with National Highways (NH) of UK to consider a new technology and its use case for the production of a Technology Implementation plan. The COWI bridge inspection platform was selected by NH as the new technology, with the use case being the regular inspection of NH bridge stock on the strategic network.

As discussed in the main section of this report, the technological framework assumes that a use case has been decided for the identified technology. Therefore, before applying the framework the potential use cases of the COWI Virtual Platform were discussed. NH confirmed that this technology could not be used to replace their current inspections because these inspections require an ability for physical interventions (to hammer tap the bridge). However, there was potential for it to be used to ‘keep a watch’ on particular defects that inspectors had noted. This suggested separate use cases, which would be recorded in the system as such – i.e. a separate appraisal for each use case.

With respect to the elements of the implementation framework, high-level policy and legislation was considered first. There are restrictions on use of drones in UK, for example they cannot be used over

live traffic and need to be used within the line-of-sight of the operator, which restricts their use. Additionally, there is no policy to use drones in NH.

In terms of capacity building, there would need to be a structured 'training' programme to satisfy inspectors that defects are being picked up properly. This would include:

a) Calibration with visual inspections

b) Useful to get statistics of false positives and false negatives – false positives are ok, they can be filtered out during the 'virtual inspection', however false negatives would be an issue.

c) Information on how long it took to be able to train the AI, and whether that effort goes down over time if extending use of the technology to other bridges

It was also noted that the technology could change how bridge inspectors operate collaboratively and the QA process, which should be elaborated in the roadmap. There are also potential "Ethics / privacy issues" – e.g. drone footage of vehicle registration plates. Change management strategies would need to be developed to facilitate a smooth transition and address any resistance to change.

In summary, NH decided that the current policy and legislation barriers were too substantial to implement the technology in the near future. Therefore, a roadmap was not produced. This shows the value of using the framework to consider the essential conditions that need to be in place for a technology to be implemented.

6.3 Workshop (Copenhagen, 11th and 12th March 2024)

The implementation framework was presented in a Training Workshop held in Copenhagen. Attendees at the workshop included representatives from the Flemish Roads and Traffic Agency (AWV), Transport Infrastructure Ireland (TII), Norwegian Public Roads Administration (NPRA), Rijkswaterstaat (RWS) in the Netherlands, and the Danish Roads Directorate (DRD).

A practical session was held with participants in which two technologies were presented for NRAs to evaluate. COWI presented their Virtual Inspection Technology for Bridges; and NIRA Dynamics presented a technology and data product which produces road roughness data from sensors and crowd-sourced data from vehicles in the Volkswagen group.

Following the presentation the attendees were given access to the Confluence tool hosting the implementation framework. Group sessions were undertaken in which attendees commenced development of an implementation plan by answering the questions raised by the framework (as described in section 3). As time was limited the participants focused on 2 or 3 aspects of the framework. Feedback included discussion around explicit incorporation of change management into the framework, feedback to suppliers during implementation planning, early involvement with the NRA's procurement office around potential opportunities and barriers, and the need to address scaling up of the technology during implementation planning.

A full explanation and details on the implementation plan discussions are included in the INFRACOMS Workshop 4 report.