CEDR

Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

CEDR Contractor Report 2019-04

Infravation Summary Report

Infravation

An Infrastructure Innovation Programme

December 2019

Compiled and edited by Aingeal Flanagan (on behalf of Infravation project coordinator Peter Wilbers, Rijkswaterstaat)

Published by CEDR's Secretariat-General

Purpose of the report End-of-activity report; for information only

CEDR reference CR2019-04

ISBN 979-10-93321-52-3

Disclaimer

Executive summary

This report outlines the main achievements and conclusions of Infravation, the ERA-NET Plus action on infrastructure innovation, which ran from 2014 to 2018.

The aim of the Infravation programme was to support research that would generate by 2018 near-market ready innovative solutions for today's road infrastructure problems while improving the cost-performance ratio of the infrastructure by 50 per cent.

The European Union's ERA-NET Plus (European Research Area Network – Plus) tool was used to organise a joint transnational call for research proposals, thereby generating new transnational research in the field of road infrastructure (e.g. pavements, bridges, and tunnels) in areas where research gaps had been identified.

Infravation was based on the funding principle of a 'real common pot', which merged funding from 11 NRAs in Europe, Israel, and the USA and EC top-up funding, enabling a real leverage of individual funders' contributions while providing a new common governance structure for the R&D projects funded. This was the first time that the EC contributed financially to a programme of CEDR-defined research. A key feature of the common funding pot—which was worth €9.575 million (€8.837 million was used in the end)—was that all projects were funded by the whole consortium of funders. From over 100 initial applications, nine projects were selected for the programme:

1 AlterPave: use of end-of-life materials, waste, and alternative binders as useful raw materials for pavements construction and rehabilitation
2 BioRePavation: innovation in bio-recycling of old asphalt pavements
3 ECLIPS: enhancing concrete life in infrastructure through phase-change systems
4 FASSTbridge: fast and effective solution for steel bridges life-time extension
5 HEALROAD: induction heating of asphalt mixes to increase road durability and reduce maintenance costs and disruptions
6 SEACON: sustainable concrete using seawater, salt-contaminated aggregates and non-corrosive reinforcement
7 SeeBridge: automated compilation of semantically rich BIM models of bridges
8 SHAPE: predicting strength changes in bridges from frequency data safety, hazard and poly-harmonic evaluation
9 SUREBridge: sustainable refurbishment of existing bridges

A total of 48 partners from 10 countries were involved in the projects. The partners involved included private companies, research institutes, universities, and road owners. There was a high level of industry participation, which ensured that the resulting products have a high chance of commercialisation. Another feature was that 8 of the 9 awarded projects had both university and industrial partners, thereby promoting research to application.

Participants reported that the Infravation programme generated a lot of research results for comparatively little money. Moreover, the results had a high relevance potential for several of the funders, which means greater market opportunities for industrial innovations. It was felt that the US-European-Israeli cooperation generated great added value, which is also a great incentive for industry.

The Infravation tool has proven to be an interesting mechanism with which to engage transnational research in both Europe and the USA. The programme management was well considered and developed and could be replicated for future initiatives. The nine projects selected were of extremely high quality and have resulted in a high number of potentially exploitable technologies and various business options to take them forward. However the management processes required to justify the EC funding required a two-stage tendering process and imposed additional overheads not found in the traditional CEDR programme.

The support of road authorities was instrumental in bringing added value to the programme and scientific outputs.

Table of contents

Abbreviations

Abbreviation	Definition
AC	asphalt concrete
BFRP	basalt fibre-reinforced polymer
BIM	building information modelling
CEDR	Conference of European Directors of Roads
CFRP	carbon fibre-reinforced polymer
CSA	Coordination and support action
DOT	Department of Transportation (USA)
EC	European Commission
ERA-NET	European Research Area Network
ETA	European Technical Agreement
FHWA	Federal Highway Administration (USA)
GFRP	glass fibre-reinforced polymer
H2020	Horizon 2020, the EU Framework Programme for Research and Innovation
IDM	information delivery manual
IFSTTAR	The French Institute of Science and Technology for Transport, Development and Networks
LCA	life cycle assessment
MVD	model view definition
NDT	non-destructive testing
NRA	national road authority/administration
PA	porous asphalt
PCM	phase change material
PSV	polished stone value
R&D&I	research, development, and innovation
RAMSHEEP	a risk-driven maintenance concept used by the Ministry of Infrastructure and the Environment of The Netherlands and Rijkswaterstaat (RWS)
RAP	reclaimed asphalt pavement
RWS	Rijkswaterstaat, Dutch Directorate-General for Public Works and Water Management
SHCC	strain hardening cement composites
SMA	stone mastic asphalt
TRL	technology readiness level

Preface

This report provides a summary of the Infravation programme.

It details the challenges each of nine Infravation projects sought to address and the technologies they developed. It also highlights the overall conclusions of the Infravation programme and provides an overview of CEDR's role in it.

It was compiled at the request of Rijkswaterstaat and brings together information from the following sources:

- The summary report 'Infravation Programme and funded Research Projects' by Peter Wilbers, 2019
- The 'Infravation Business Case' report by Arno Willems, August 2018
- The ERALearn2020 report 'Case studies of current approaches for aligning national research strategies, programmes and activities' by the Institut National de Recherche Agronomique (INRA).
- Two internal CEDR paper drafted to frame the Infra4DFuture project:
  - Final summary report of the WGI CSA reflection group, 20.11.2017
  - Memo in preparation for the TRB 2018 and further
- Infravation website – www.Infravation.net
- Proposal Preparation and Submission – Miriam Stephan and David Doerr, TUV Rheinland, Infravation Call Secretariat
- Infravation lessons learned: The viewpoint of coordinator RWS (Cees Brandsen).

1 The Infravation programme

1.1 Background and CEDR's role

The impetus to launch the Infravation programme was the realisation that Europe needed to redefine its transport system for the twenty-first century. The performance and the cost-efficiency of the system needed to be improved in order to meet future challenges. In short, there was an urgent need for effective innovation for all components of the system, including vehicles, infrastructure, logistics, etc.

Following the global economic crash, transport ministries were faced simultaneously with ever increasing budget pressures and ever tougher challenges to accommodate increased traffic growth, minimise congestion, maintain services in the face of increasing climate change effects, and deliver on environmental and societal objectives while at the same time maintaining and replacing ageing infrastructure assets. Because these challenges were common to countries with mature transport networks both in Europe and further afield, it was decided that it would be best to address some of these challenges at transnational level, sharing working practices and pooling resources.

Infravation was the first time that the European Commission contributed financially to a programme of CEDR-defined research. While the EC had contributed to the ERA-NET ROAD I and II initiatives, it had funded these programmes' processes (coordination and events) rather than their research projects. In the case of Infravation, however, the EC's financial input went straight into the research budget for the projects (see section 2.3).

According to CEDR's Strategic Plan 3 2013–2017 (SP3), the **objective of Infravation** was 'to generate by 2017 innovative solutions for today's road infrastructure problems while at the same time improve the cost-performance ratio of the infrastructure by 50%.'

SP3 defined **CEDR's Infravation strategy** as follows:

- 'to create a group of CEDR members (Task group I2: Infravation) to work with other stakeholders to jointly make proposals for the technical content of the research call to be launched in 2014 and to jointly fund the call;
- to support an ERA-NET PLUS under the last call of the Commission's 7th Framework Programme by submitting a proposal to the final call of FP7 in February 2013;
- to support a scoping study in 2013 to generate the state-of-the-art basis for the research projects to be funded under the Infravation 2014 call;
- to contribute to the implementation of the Infravation 2014 call, including selection of the projects and monitoring the progress of the projects;
- to support through a continuous process the dissemination of the results of the projects to the road infrastructure community at large;
- to interact with CEDR's to align the technical content of Infravation with TG Research' transnational research calls.'

SP3 also defined **the output CEDR expected from Infravation:**

- 'recommendations to CEDR on the application of advanced materials, systems, and techniques in road infrastructure, with the objective of improving the cost-performance ratio of the infrastructure by 50%;
- workshops and seminars to transfer the findings to the road community;

- to contribute to positioning CEDR as a reliable stakeholder for the EC and other existing institutions.'

1.2 Project structure

The ERA-NET Plus (European Research Area Network – Plus) tool was used to organise a joint transnational call for research proposals, thereby generating new transnational research in the field of road infrastructure (e.g. pavements, bridges, and tunnels) in areas where research gaps had been identified. The action was launched in March 2014, following an initial exercise to scope key areas of interest.

Infravation was structured around three main bodies (see Fig. 1): '1) the Steering Group, which brought together all funding partners and was the highest decision-making body; 2) the Management Group, which was responsible for the day-to-day coordination and management of Infravation activities and advised the Steering group; and 3) the Scientific Panel, which was composed of independent experts who jointly provided technical advice on the projects. It was the job of the Scientific Panel to closely follow-up the progress of the projects and to liaise regularly with the projects' representative in order to facilitate the exploitation of the results. In addition, the Programme Coordination Group scientifically monitored the projects in order to foster cooperation and complementarity among them and promote joint dissemination of results. It was composed of the work package leaders responsible for the project selection and monitoring, the project coordinators, and the chair of the Scientific Panel.'[1]

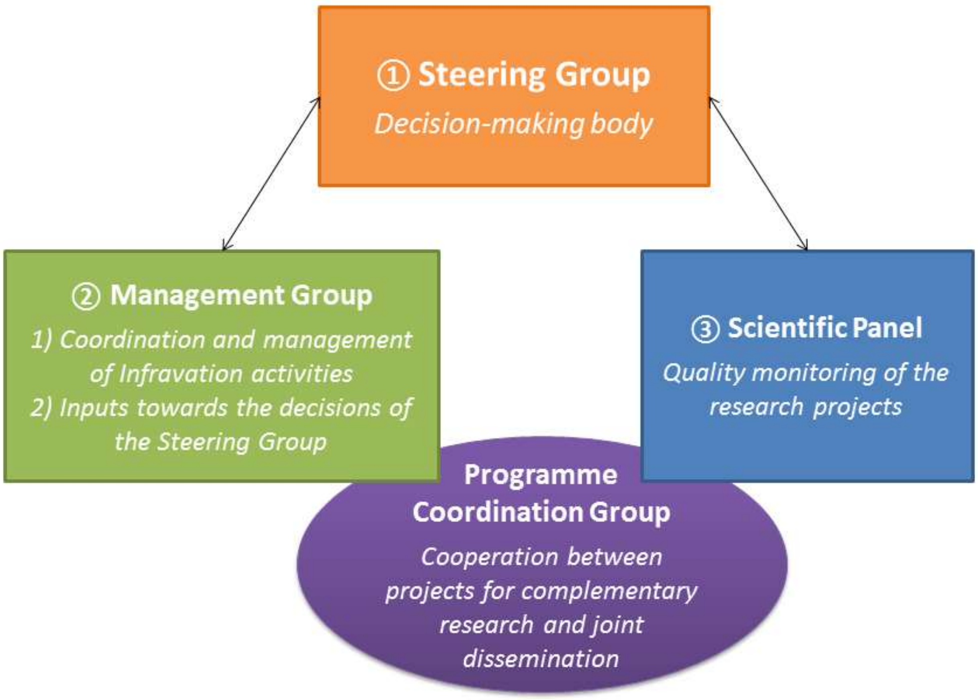

Figure 1: Governance of Infravation (Source: Infravation Description of Work)

[1] ERALearn2020 report

1.3 Funding

Infravation was based on the funding principle of a ‘real common pot’, which merged national and EC top-up funding, enabling a real leverage of individual funders’ contributions while providing a new common governance structure for the R&D projects funded. This ensured that the best expertise could be used, regardless of nationality, thereby minimising programme management and allowing for maximum use of resources for transnational research cooperation. Another key point of the common funding pot—which was worth €9.575 million—was that all projects were funded by the whole consortium of funders from a unique, common, and consensual decision of the college of funders. The scheme relied on the commitment of funders to support a dedicated call for R&D&I. This flexibility allowed the programme to act and react quickly to research needs.

The Infravation common pot comprised funding from 11 NRAs from Europe, Israel, and the USA, and benefited from a financial top-up from the EC. The European funding NRAs were Denmark, France, Germany, Iceland, Italy, the Netherlands, Norway, Spain, and Sweden.

Besides the funding for R&D&I provided via the common pot, Rijkswaterstaat (RWS) also paid for communication support (FEHRL) and management support (TUV). This is a further demonstration of the strong commitment of the funders to supporting R&D&I activities.

The common pot approach also had a number of benefits at operational level. Indeed, the delegation of responsibilities to a single entity is a requirement when applying a real common pot.[2] As one of the initiators of the programme, Rijkswaterstaat (RWS) covered most of the coordination and management costs by making a significant in-kind contribution in order to demonstrate the effectiveness and benefits of such an approach. It also assumed the role of the contracting and funding body for the programme.

There were two components to Infravation’s management and communication costs, which amounted to approximately €1 million:

1 the subcontracting of two consortium partners for management and communication support and
2 (in-kind) costs at RWS for coordination and management

In total, €2,353,044 was received from the EC. The total amount eventually spent on research was € 8,837,447 EUR. When management and communication costs are taken into account, this means that the EC’s contribution was approximately 23.9%.

The EU funding fell within the scope of SST.2013.1-3. ERA-NET Plus ‘Advanced systems, materials and techniques for next generation infrastructure’. The European Commission and Infravation liaised very closely to ensure the best complementarity of the Infravation Call and the ones in Horizon 2020.

There was significant industry support for the Infravation concept because it bridged a gap in research funding for infrastructure between that provided by the EC and ERA-NET projects. Typically, EC funding for research and innovation runs to around €3-4 million for projects seeking to reach a maximum TRL of 8, whereas CEDR Transnational Research projects are typically €250,000–750,000 for higher TRL-level projects aiming at projects that could be implemented readily by NRAs. This funding enabled R&D&I across a wide range of TRLs up to and including commercially ready products.

[2] ERALearn2020 report

1.4 Scoping

To help identify the key topics and further inform the development of the call for proposals and subsequent evaluation and negotiations, an Infravation scoping study was completed in 2013. This study involved international experts who identified the priority areas of the NRAs involved regarding advanced materials and systems and resulted in an Infravation 'scope document', which was published in February 2014.

The research themes also addressed the challenges identified in the European Commission's White Paper on Transport: *Smart, Green and Integrated Transport*. Its objective is to enable a high-quality infrastructure offering high service levels to the user/economy/society through solutions for both new and existing infrastructure.

The word 'infrastructure' was used as an umbrella for the different constituting parts (i.e. pavements, bridges, tunnels). The Infravation scope was divided into the following seven challenges, each of which had a clear focus:

A Advanced predictive infrastructure performance processes
B Enhanced durability and life-time extension
C Rapid and non-destructive methods for routine quality and performance checks of materials and construction
D Keeping freight routes open through zero-intrusive maintenance
E Ensuring infrastructure performance under all weather conditions
F Resource and energy efficiency in road construction and maintenance (eco-design)
G Virgin material reduction by substitution or recycling

1.5 The transnational call

The programme adopted the ERA-NET evaluation scheme, which includes a two-step approach and involves external evaluators.

The Infravation transnational joint call was launched in March 2014. Its aim was to 'support near-market ready research and hence lead to the demonstration phase of innovative products, technologies and services for road transport.'[3]

The focus of the call was on projects that aimed for cost-effective, near market-ready systems, materials and techniques in road infrastructure construction and maintenance, including repair, retrofitting, and revamping. More than 100 light proposals with coordinators from 10 different countries were submitted, involving 521 partners from 28 countries. The total requested amount of co-financing was about €122.4 million. This meant an average requested amount per proposal of €1.2 million.

The evaluation of the submitted light proposals ended on 30 September 2014, with coordinators submitting full proposals by 30 November of the same year. These were evaluated by independent international experts on road and bridge infrastructure innovation between December 2014 and April 2015.

Nine successful projects were announced in April 2015, with grant negotiations running to August 2015. The successful projects were:

[3] ERALearn2020 report

10 AlterPave: use of end-of-life materials, waste and alternative binders as useful raw materials for pavements construction and rehabilitation
11 BioRePavation: innovation in bio-recycling of old asphalt pavements
12 ECLIPS: enhancing concrete life in infrastructure through phase-change systems
13 FASSTbridge: fast and effective solution for steel bridges life-time extension
14 HEALROAD: induction heating of asphalt mixes to increase road durability and reduce maintenance costs and disruptions
15 SEACON: sustainable concrete using seawater, salt-contaminated aggregates and non-corrosive reinforcement
16 SeeBridge: automated compilation of semantically rich BIM models of bridges
17 SHAPE: predicting strength changes in bridges from frequency data safety, hazard and poly-harmonic evaluation
18 SUREBridge: sustainable refurbishment of existing bridges

Table 1: Comparison summary of Infravation and CEDR project conditions

	Infravation ERA-NET Plus	CEDR Transnational Programme
Countries from which candidates are eligible to coordinate a proposal	the Netherlands, Denmark, France, Germany, Iceland, Israel, Italy, Norway, Spain, Sweden, and the US (i.e. countries that are funding providers to the Infravation call)	All European countries
Additional countries where project partners can come from	the remaining EU28 countries plus further countries associated with the EU Framework Programme (i.e. Switzerland, Liechtenstein, Turkey, FYROM, Serbia, Albania, Montenegro, Bosnia & Herzegovina, Faroe Islands, Republic of Moldova)	Since 2017, eligibility has been extended globally.
Funding restrictions	2/3 funds to be spend in the Netherlands, Denmark, France, Germany, Iceland, Israel, Italy, Norway, Spain, Sweden, and the US. At least two partners, no more that 70%, to one country or partner.	At least two partners, no more that 70% to one country or partner.
Funding rates	Industry/SME; 100% direct costs + 25% overhead. Non-profit organisations: 100% direct costs + 25% overhead	100% of all costs
Maximum project size	€1.5 million	Not applicable
Project evaluation	Two-stage process. Funding countries make first-stage review. EU external scientific evaluators make final ranking of successful proposals.	One evaluation made by funding countries.
Audit certificates	Mandatory per every €375.000 requested funding Eligible costs of first-level audit: max. €3,000 per audit certificate Infravation - Second level audit The funding body may conduct a second-	Not applicable

	level audit at any time The EC can conduct audits	

Source: Infravation Guide for Applicants 2014, CEDR

1.6 International dimension and high industry participation

The nine selected projects involved 48 partners from 11 countries (including one Brussels-based, European association). The partners/organisations involved included private companies, research institutes, universities, and road owners. The table below lists the countries represented in each project.

Table 2: Countries participating in Infravation projects

Project	Countries represented
AlterPave	**Spain** (2), Sweden, USA, Italy
BioRePavation	**France** (2), USA (2), Netherlands, UK
ECLIPS	**USA** (2), Switzerland, Netherlands, Spain
FASSTbridge	**Spain** (3), Germany (2), France, Italy, USA
HEALROAD	**Spain**, Netherlands (2), Germany, UK, Belgium
SEACON	**USA** (2), Italy (4)
SeeBridge	**Israel**, Germany, USA (2), UK (3)
SHAPE	**Italy**, UK
SUREBridge	**Sweden**, Netherlands, Italy

Note: bold print indicates the project's lead partner

The level of representation per country differed considerably: the US had the highest level of representation with 10 organisations involved in 6 projects and leading 2; Italy had 8 organisations involved in 4 projects, leading one. Spain led the most projects (3), with 7 organisations involved in 4 of the 9 projects. Other countries with high levels of representation were UK (6), Netherlands (5) and Germany (4).

While various EC calls have promoted twinning with the USA or other countries, this was the first time where joint funding was awarded.

Another important element was that there was a high level of industry participation, namely 22 out of the total of 48 organisations involved, with the remainder largely universities and research organisations, many of which have a significant industrial focus. The industry partners included some very large organisations, including Dragados (world's largest concession contractor in PPP contracts), Acciona (€7.25 billion turnover, 37,400 employees), Heijmans (€1.4 billion turnover and 4,400 staff), and Owens Corning ($6.4 billion sales 2017, 19,000 employees). This ensured that the products developed have a high chance of commercialisation, with identified markets and sales channels around the world.

1.7 Scientific collaboration

As already mentioned above, one of the requirements for a project was that it had to feature transnational cooperation, with the number of partners per project ranging from 2 to 8 (although 5–6 partners was the norm). Five of the nine projects awarded involved partners from Europe and the USA, one involved partners from Europe, Israel, and the USA, with the remaining three involving collaboration between European partners only.

While many European and USA universities have links and many European companies have facilities in the USA or vice-versa, this is the first time that a research fund has not only made joint research possible, but positively promoted it.

Another feature was that 8 of the 9 awarded projects had both university and industrial partners, thereby promoting research to application.

As well as collaboration within individual projects, some projects also featured collaboration with road owners and US State DOTs, and in many cases scientific collaboration between projects, as outlined below.

1.7.1 Collaboration between SEACON and SHAPE

As part of the SEACON project (sustainable solutions for concrete construction using seawater and fibre-reinforced polymers), a pedestrian bridge was constructed in 2016 and a highway bridge constructed in 2018.

The SHAPE project developed an NDT monitoring system to identify bridge condition using frequency characteristics. The SHAPE project used its equipment to fit the pedestrian bridge with vibrating wire gauges on the CFRP (Carbon Fibre-reinforced polymer) tendons and BFRP (Basalt Fibre-reinforced polymer) reinforcement. Deflection was monitored periodically. In March 2018, approx. two years after being opened, the bridge was monitored using the SHAPE accelerometer system.

Figure 2: the SHAPE monitoring setup

Once the highway bridge is completed (Figure) a similar reference monitoring session will be carried out with and without traffic loading and for a 24 hour period. The plan is then to fit the bridge with a permanent SHAPE system to allow continuous monitoring.

Figure 3: Halls River Bridge

Collaboration between the SEACON and SHAPE projects has been very positive and highly beneficial for both projects to date. Ongoing collaboration is planned for the long-term with the aim of deploying and testing project outcomes in operational environments (at TRL 8).

The project partners wish to acknowledge the exceptionally positive support of all highway authorities sponsoring the Infravation scheme and the project management team, without whom the project developments could not have taken place.

1.7.2 Collaboration between AlterPave, BioRePavation, and HEALROAD

Both the AlterPave and BioRePavation projects sought to increase the amount of RAP in asphalt mixes. To this end, they held joint dissemination activities. A common framework in the Life Cycle Analysis of the technologies was developed for both projects and a common deliverable including all the findings of the Western Research Institute (WRI), a partner of both projects, was drafted.

The findings of the AlterPave project have been used in the HEALROAD project as follows:

- Recyclability of HEALROAD mixes. One of the rejuvenators tested in AlterPave was used in HEALROAD according to the methodology proposed therein.
- The same method for the impact assessment of the AlterPave and BioRePavation was selected also for the HEALROAD LCA for comparison purposes.
- By-products used in AlterPave were tested to check their suitability for induction heating. Although it was only partially successful, a new project has started as a result of tests.

1.8 Monitoring

1.8.1 Scientific Monitoring

As mentioned above, the Scientific Panel monitored the scientific progress of the projects in the programme, which was an innovation because in many programmes, although the projects are indeed assessed, no one ‘judges’ the final results overall.

The Scientific Panel and project representatives met twice a year. The TRL assessment was undertaken in two phases covering the development to TRL 4+ and beyond.

The project partners felt that the Scientific Panel was helpful when compiling quarterly reports and for quality control. The members of the panel devoted a lot of time to contributing to a successful follow-up of the projects. The TRL assessment methodology was felt to offer the greatest added value when reviewing progress.

There was good communication and interaction between the projects and the Scientific Panel. The project partners felt they received useful feedback from the Scientific Panel, although more feedback on deliverables would have been appreciated. The lessons learned in this respect could be useful for future programmes.

Generally, there was a good level of demonstrations for the 2-year project timeframe. The industry partners argued that the time available for the project was short, which meant that there was no time to develop a prototype. It was also felt that the business case had to be developed too early.

1.8.2 Assessment of the maturity of the innovation (Technology Readiness Level)

The Technology Readiness Level (TRL) is a well-established technique for assessing the maturity of a technology. Levels range from blue sky ideas (TRL 1) to full market deployment (TRL 9). While it is well-established in typical manufacturing and product settings, the assessment and interpretation are less widely used in the civil engineering and highway research sectors.

A significant innovation in Infravation was the development of a process that was based on structured questions and was designed to allow for an objective assessment of the TRLs achieved by the various projects. This was useful for both communicating research outcomes to stakeholders and for identifying gaps to help develop the technology. The process was expressly not used to evaluate investment requirements to reach a higher TRL, estimate the impact of the technology, analyse the market for the technology, or serve as a sole indicator as to whether the project should continue or not.

The TRL assessments were undertaken by an expert panel. To assist the panel in making the assessment, the project team completed a questionnaire and gave its assessment of the TRL. The questionnaire had 8 main questions, each with several supplementary questions to further define the exact state of the technology TRL. The 8 main questions/tasks asked were:

1 Describe the technology
2 Describe the various constituent parts of the technology. How do they fit together and interact with one another?
3 Describe the envisioned deployment of this technology
4 How have the technology’s subsystems, components and/or concepts been tested individually?
5 How has the integration of the various components and systems been tested?
6 Has a demonstration of the *full technology* been conducted, or a prototype constructed?
7 Describe the most recent test conducted on the full technology. What precisely was tested, why and how did it go?
8 How has the user community been included in the technology development process?

Additionally, the project teams were required to undertake a test assessment against the TRL scale, shown below.

Table 3: Technology Readiness Level (TRL) scale

	TRL	Description	To achieve the given TRL, you must answer yes to EVERY question. Discuss any uncertain answers.
Basic research	**1**	**Basic principles and research**	• Do basic scientific principles support the concept? • Has the technology development methodology or approach been developed?
	2	**Application formulated**	• Are potential system applications identified? • Are system components and the user interface at least partly described? • Do preliminary analyses or experiments confirm that the application might meet the user need?
	3	**Proof of concept**	• Are system performance metrics established? • Is system feasibility fully established? • Do experiments or modelling and simulation validate performance predictions of system capability? • Does the technology address a need or introduce an innovation in the field of transportation?
Applied Research	**4**	**Components validated in laboratory environment**	• Are end user requirements documented? • Does a plausible draft integration plan exist and is component compatibility demonstrated? • Were individual components successfully tested in a laboratory environment (a fully controlled test environment where a limited number of critical functions are tested)?
	5	**Integrated components demonstrated in a laboratory environment**	• Are external and internal system interfaces documented? • Are target and minimum operational requirements developed? • Is component integration demonstrated in a laboratory environment (i.e. fully controlled setting)?
Development	**6**	**Prototype demonstrated in relevant environment**	• Is the operational environment fully known (i.e. user community, physical environment, and input data characteristics as appropriate)? • Was the prototype tested in a realistic environment outside the laboratory (i.e. ***relevant environment***)? • Does the prototype satisfy all operational requirements when confronted with realistic problems?
	7	**Prototype demonstrated in operational environment**	• Are available components representative of production components? • Is the fully integrated prototype demonstrated in an ***operational environment*** (i.e. real-world conditions, including the user community)? • Are all interfaces tested individually under stressed and anomalous conditions?
	8	**Technology proven in operational environment**	• Are all system components form, fit, and function compatible with each other and with the operational environment? • Is the technology proven in an operational environment (i.e. meet target performance measures)? • Was a rigorous test and evaluation process completed

			successfully? • Does the technology meet its stated purpose and functionality as designed?
Implementation	**9**	**Technology refined and adopted**	• Is the technology deployed in its intended operational environment? • Is information about the technology disseminated to the user community? • Is the technology adopted by the user community?

At the assessment, the project team presented their results to the expert panel, after which the panel reviewed and agreed on the application(s) to be assessed, each panellist suggested an initial TRL together with 2–3 points to justify their reasoning. The panel then assessed each application together in order to reach a final TRL.

This assessment helped shape the research direction of the projects and informed some of the market opportunity decisions made by the partners, as outlined below.

1.8.3 Impact assessment

In 2018, Rijkswaterstaat commissioned a report on the business cases for all nine Infravation projects[4] in order to gain a better understanding of their **feasibility and fitness for purpose specifically for the Netherlands**, but also for other countries.

To this end, all nine projects were assessed using the RAMSSHEEP criteria (see table below).For each criterion, the projects were rated against current technologies on a scale of -2 (very negative), -1 (slightly negative), 0 (neutral), 1 (slightly positive) and 2 (very positive). Where relevant, a distinction was made between the characteristics of the innovation itself and its impact on the RAMSSHEEP aspects of the infrastructure. The scores are shown in the table below.

It is important to note that at the time the study was conducted (as of 1 June 2018), three of the nine projects—SHAPE, HEALROAD and BioRePavation—provided little if any insight into their own business cases; there was often a lack of reliable data on initial and/or maintenance costs and potential returns were completely unknown. For these projects, the authors of the report assessed the economics aspect from a qualitative perspective.

Although this business case assessment related specifically to the projects’ feasibility and fitness for purpose *in the Netherlands*, the results are quoted in chapter 3 because some of them include references to the projects’ potential value for other countries. However, it must be noted that these assessments are written purely from a Dutch perspective.

[4] ‘Infravation Business Case’ by Arno Willems, August 2018

Table 4: RWS's scores for each Infravation project based on a RAMSSHEEP analysis

	Aspect	SHAPE	Seac	Eclips	BioR	Healr	Alterp	Seebr	Surebr	Fasstb
R	Reliability of infra	1	-1	1	0	1	0	-1	1	-1
	Reliability of innovation	-2	1	0	0	1	0	-1	1	0
A	Availability of infra	1	1	1	0	2	0	1	1	0
	Availability of innovation	-1	-1	-2	-1	1	0	-1	1	-1
M	Maintainability of infra	2	1	1	0	2	1	1	-1	0
	Maintainability of innovation	1	0	0	0	0	1	1	1	0
S	Safety of infra	1	-1	0	0	0	0	1	0	0
	Safety of innovation	0	1	0	0	0	0	0	0	0
S	Security	-1	0	0	0	0	0	0	0	0
H E	Health and environment	0	1	-1	2	0	1	0	1	1
E	LCC	1	0	0	0	1	0	2	1	1
P	Policy/politics	1	-1	-1	1	1	2	1	1	0
	TOTAL	**4**	**1**	**-1**	**2**	**9**	**5**	**4**	**7**	**0**

As there is not any framework/tool at the moment to follow-up the innovation path and its implementation, it has been suggested that a mechanism be set up to follow-up Infravation outcomes over time.

The funders pointed out that the Infravation programme generated a lot of research results for comparatively little money, and that these results had a high relevance potential for several of the funders, which means greater market opportunities for industrial innovations developed within the Infravation programme. Indeed, it was felt that the US-European-Israeli cooperation generated great added value, which is also a great incentive for industry. The industrial partners pointed out that while it would have been faster to undertake the projects alone, together, the projects were bigger together, which is important for industry.

The project partners argued that there were small consortia and large projects, with the call focussed on infrastructure, so being applied research. As such, it was difficult to have demonstrations, which would need funding to achieve the TRL required. It was also stated that demonstrations scale can be TRL 4 in the laboratory.

It was agreed by all that implementation remains a difficult challenge. When considering how to achieve this, it is felt that there initially needs to be trust in the technology. Support funding (such as H2020 tools) could help early adopters. It will also be important to share the risk between the public sector and industry.

It was also suggested that a business angle could be sought to foster the impact of the programme's innovation.

2 The nine Infravation projects

Nine sets of innovations were funded by the Infravation programme. This chapter provides a summary of each project, details of the end users of the technology developed and their requirements, gives the TRL at the end of the project, and outlines any remaining challenges.

2.1 AlterPave

The focus of the AlterPave project was on the **use of end-of-life materials, waste, and alternative binders as useful raw materials for pavement construction and rehabilitation**.

The overall aim of the project was to demonstrate an innovative and integrated approach to the sustainable construction of roads, taking into consideration the whole life cycle of the infrastructure by:

- enhancing the resource- and cost-efficient use of alternative materials,
- ensuring the recyclability of the roads developed using alternative green materials (design for reuse), and
- implementing a 'circular economy approach' by taking advantage of the actual by-products and waste produced by regional industries.

The project focused on two main pavement components: firstly, it looked into ways of replacing virgin aggregates with recycled materials and by-products. Secondly, alternative green binders (such as waste engine oils and bio-fluxing agents) were integrated into the mixes to reduce the use of petroleum-based binders.

Three technologies were developed during the project:

1 trials of asphalt mixtures with high percentages of RAP and industrial aggregates, such as electric arc furnace slags, foundry sand, and bio-rejuvenators used to recover properties of the old bitumen from RAP;
2 development of a tool (AlterPavest, see Figure 3) to assess the technical, environmental, and economic feasibility of using industrial aggregates on a specific road project;
3 the development of a tool that allows easy labelling of data on road construction, accessible from any mobile device (see Figure 4).

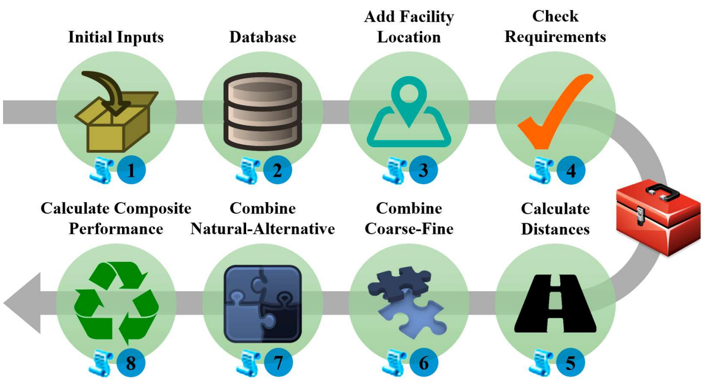

Figure 4: The AlterPavest tool

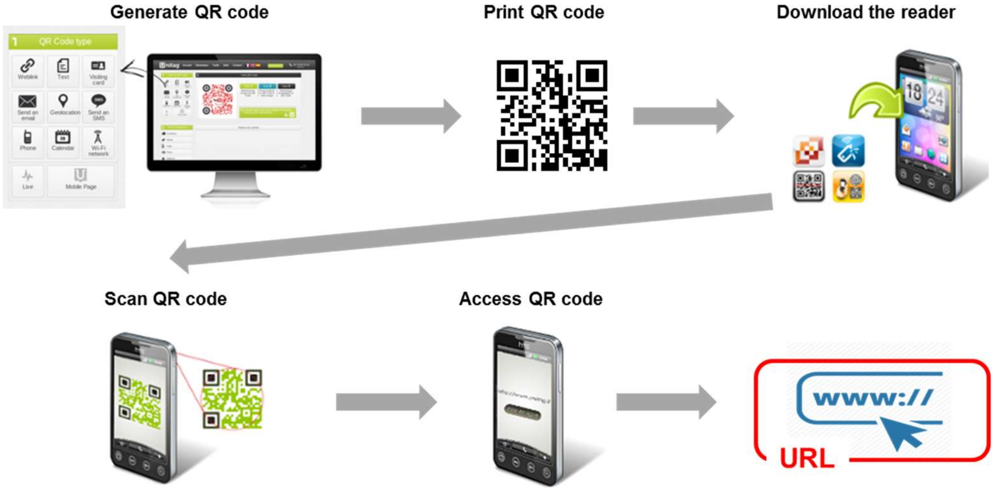

Figure 5: Smart labelling solution

In developing these tools, the AlterPave project addressed issues regarding the scarcity of high-quality aggregates for asphalt, by replacing them with industrial wastes, increased the percentage of RAP in asphalt mixes, and demonstrated how rejuvenators can recover properties of old RAP. Additionally, industrial wastes can now be used as valuable raw materials.

The AlterPavest output served to:

- increase confidence in the use of secondary materials in asphalt mixes;
- ensure the technical, economic, energy-related, and environmental feasibility of using alternative materials in a specific project.

The smart labelling solution will help future road maintenance and rehabilitation thanks to the tracking the knowledge of the materials that were added in a road construction through its lifecycle.

The end user of the technology and user requirements

Technology	**End user**
AlterPave mixes	Road authorities. Same technical specifications and requirements as with conventional materials would apply.
AlterPavest tool	Contractors and/or road authorities. The tool would be used to assess the convenience of using alternative materials in a specific project.
Smart labelling solution	Contractors and/or road authorities.

Technology readiness level

At a review meeting, it was concluded that the technology satisfied all of the requirements indicated by a TRL 5 and most requirements of a TRL 6. The technology prototype was tested in a realistic environment outside of the laboratory in an accelerated test.

Remaining technical or design-related challenges

Asphalt mixes: the real effect of rejuvenators is not fully developed at binder level. The blends of virgin, extracted aged binders, and rejuvenator assumes 100% blending, which is the upper limit but not necessarily the true level depending on mixing conditions. The long-term durability of their effect is still not determined.

- Other types of bitumen and other types of RAP sources should be tested (especially for the rejuvenator effectiveness).
- The mixes have been validated for AC mixes. Other types of asphalt mixes should be tested and validated (PA, SMA)

AlterPavest: the tool is theoretically ready for use in Spain. It could be adapted to other regions or countries as long as the required information (technical and environmental requirements and specifications and the correspondent maps) is available.

Smart labelling solution: the solution is theoretically ready for use in the road section demonstration. It could be adapted to other materials by modifying the material section. Currently the access page is linked to a QR code, but other pages could be easily linked to other QR codes to get access to different places.

Rijkswaterstaat business case assessment

'Applying the principles of circularity fits in seamlessly with the global trend and therefore with RWS's sustainability policy. **Infravation's test results are promising, although the tests in various countries are producing both positive and negative results**. **The assumption is that performance is strongly dependent on the precise formula used for the mixture.**

It is also important to note that both the mixtures and the bio-binders have been used in the Netherlands for years and that this 'innovation' is therefore nothing new for the Netherlands, except for the fact that materials are documented in order to facilitate future reuse. Rijkswaterstaat has not yet validated any products containing bio-rejuvenators or additives. **The innovation could be more of a novelty for other infrastructure managers outside the Netherlands and could well be of interest there. However, the optimal composition of the asphalt mixture still needs to be determined and tested under motorway conditions**.'[5]

[5] 'Infravation Business Case' by Arno Willems, August 2018

2.2 BioRePavation

The focus of the BioRePavation project was on **innovation in the bio-recycling of old asphalt pavements**.

The main scientific and technical objectives of the project were to prove that alternative binders could be used to recycle asphalt pavements and achieve the same level of performance as conventional solutions with petroleum bitumen. To do so, the consortium proposed building a demonstration site where three innovative pavement solutions using biomaterials would be tested using an accelerated pavement testing facility.

The idea was that performance would be evaluated by both measuring the traffic level needed for the pavement solution to reach a distress mechanism and investigating the binder's physio-chemical evolution using an innovative non-destructive method.

BioRePavation also assessed the environmental impacts of the combined use of bio-binders and high-content of RA in asphalt mixes. Special attention would be given to airborne emissions that would be directly measured in the laboratory. Obtained data would be used to perform a risk assessment, as well as a Life Cycle Assessment (LCA) for the BioRePavation technologies.

The three alternative materials designed to help recycling and evaluated in the project are the following:

- a bio-based additive from pine chemistry designed to Increase RA content to 70%,
- a bio-based additive designed to increase compatibility between fresh bitumen, and
- a bio-bitumen designed for full replacement of fresh bitumen: Biophalt®

A novel asphalt pavement system comprised of greater amounts of recycled pavements and biomass-derived binders to limit natural resource intensity and replacement of Petroleum Bitumen (PmB) binder.

BioRePavation tested three asphalt pavement systems with a view to understanding the behaviour of the materials when mixed. Each included 50–70% RAP, GB5 mix design, and one of the three binder technologies below:

- Partial PmB replacement - BM-1: Rejuvenator (AZCHEM)
- Total PmB replacement - BM-2: BioPhalt (Eiffage)
- Partial PmB replacement - BM-3: Compatibilizator (ISU)

Figure 6: Virgin aggregate +RAP + Bitumen & Bio-Binders

Three 25-metre lengths of each pavement along with a reference section were prepared at the asphalt production plant in Tours and installed in the accelerated pavement testing carousel at IFSTTAR. This facility was able to simulate several years of traffic wear on paved test segments for fatigue testing and rutting tests under appropriate environmental conditions.

Each of the three asphalt pavement systems tested in BioRePavation was produced in an existing asphalt production facility using conventional industrial processes. However, modifications to the production facility were required for each of the systems.

Laboratory testing predicted that the materials would not have the same fatigue resistance as a conventional pavement over the pavement lifetimes, although it is frequently the case that laboratory testing does not align with field/accelerated load testing. The full-scale experiment will be used to determine the parameters necessary to calculate pavement specifications and suitable pavement mix designs for actual service life.

<u>The end user of the technology and user requirements</u>

The end users of this technology will be road authorities and contractors, who would benefit from the increased recycling and rejuvenation of materials. They would need to be confident that the new mixes would perform as per conventional mixes.

<u>Technology readiness level</u>

The TRL Panel agreed on a TRL between 7 and 8 for each of the three asphalt pavement systems tested when used as a base or intermediate layer, with on-road testing, trials in asphalt plants and in cold climates required.

For use as a surface layer, the laboratory measurements are complete and mixtures are ready to test (TRL 5). Additional testing such as skid resistance and PSV at 3 months is needed.

Remaining technical or design-related challenges

The BM2 material is unconventional and its interaction with aged bitumen has been found to not behave like more traditional fresh bitumen. It will be necessary to build a more advanced blending law for this material.

The project timescale did not allow enough time to reach 50% cracking in each pavement section during the accelerated loading. As such, it is necessary to continue full-scale testing. This will allow for a clear calibration factor between lab tests and behaviour in field that will be useful for accurate structural design. Pending funding, this second test phase was planned for November 2018. It will also be necessary to test these materials in more extreme climates (higher or lower temperature).

Rijkswaterstaat business case assessment

'BioRePavation fits in perfectly with RWS's sustainability policy on circular construction, using renewable raw materials and reducing energy consumption in the production process. **The costs and performance in terms of reliability, safety and life span are likely to be the same as in conventional applications.** The additives SYLVAROAD and EMS have been used in the Netherlands for many years, albeit in other applications than those on which Infravation focuses. Rijkswaterstaat has not yet validated any products containing biorejuvenators or additives. Test sites are required to test the additives in asphalt mixtures with high RAP (Reclaimed Asphalt Pavement) percentages (>>50%).
Additives from Eiffage based on French pine trees are promising but are not expected to be easy to apply on a large scale in the Netherlands in the short term. Additional laboratory tests will have to be carried out before they can be used on motorways. We recommend investigating the potential for using BioRePavation in the alterations to the A6 between Almere and Lelystad in 2019. Finally, we recommend carrying out a quantitative LCC analysis.'[6]

[6] 'Infravation Business Case' by Arno Willems, August 2018

2.3 ECLIPS

The focus of the ECLIPS project was on **enhancing concrete life in infrastructure through phase-change systems**.

The major premise of this project was that phase change materials can be strategically incorporated into cement-based materials to ensure a reduction in thermal cracking. The phase change material (PCM) of the appropriate phase transition temperature and enthalpy will absorb or release heat, thereby reducing the frequency and magnitude of thermal cycles (both under high ambient temperatures and in freezing climates).

Detailed characterisations of PCMs, both microencapsulated and bulk, were carried out in this project. Extensive efforts were made to develop novel silica encapsulation strategies for PCMs so that they remain inert in the concrete environment. This process was shown to be successful in the laboratory stage, and efforts are being made to scale up the process. Alternate delivery strategies for PCMs, including incorporating them in porous media such as lightweight aggregates, were also successfully developed during this work. PCM incorporated cement-based mixtures were proportioned to obtain mechanical properties comparable to those of conventional cementitious materials. It was also shown that the thermal properties of these composites can be tailored to achieve the desired performance characteristics adequately. The influence of PCM shell composition on the durability of cementitious materials were also evaluated, providing guidelines on the use of the appropriate shell type. This project also provided fundamental information as to how compliant inclusions such as PCMs change the fracture and fatigue response of concretes. The fracture parameters were enhanced using small volumes of microencapsulated PCMs, and the fatigue life is either unchanged or slightly enhanced. These results pave the way for advanced design of PCM-bearing cementitious materials for mechanical and thermal properties in pavement/bridge deck applications.

During the short-term temperature increase caused by cement hydration, as well under long term thermal cycling, PCMs were able to reduce the maximum temperature in a concrete pavement/bridge deck. A numerical tool was developed to describe the thermal benefits of using PCMs in concrete. The tool is versatile, capable of obtaining climate data from different parts of the world, accepts several pavement/bridge designs, considers user-specific mixture proportions, and predicts the temperature and thermal stress profiles to enable comparison between different design alternatives. The tool will be offered to researchers and designers interested in implementing thermal crack control design strategies of concrete pavements/bridge decks using PCM. Mixtures were developed including PCMs that were able to increase the service life of concrete subjected to freeze-thaw cycles. Combining PCMs in strain hardening cement composites (SHCC) was found to provide large strain capacity and excellent durability performance.

A novel life cycle costing approach and an environmental LCA model was developed and implemented to evaluate the life cycle impacts of PCMs in concrete. The sustainability metrics of transportation infrastructure constructed using PCM-embedded concretes were quantified. Environmental and cost assessment modules help to function as a decision support tool which can guide PCM-embedded concrete design, proportioning, and specification.

A field pavement section containing PCM was successfully placed along with a conventional pavement section, both of which are being monitored. The benefits of this novel technology to pavement agencies and contractors will be evident through the demonstration project. Several publications resulting from the work of the partners also help to provide widespread visibility to the Infravation-funded work on this novel and important topic.

The user community and end user of the technology

The pavement development and demonstration process were undertaken in conjunction with Arizona Department of Transportation (ADOT) and Cemex (concrete supplier). ADOT is interested in using the technology and a cost analysis activity is ongoing.

The technology should be of interest to contractors and infrastructure owners (roads, bridges, and other infrastructure). More durability testing and conformance with existing standards are needed. The field sections will act as enablers of this activity.

Technology Readiness Level

The TRL for this project was not assessed.

Rijkswaterstaat business case assessment

‘Although this innovation is interesting as fundamental research, the question is whether it offers added value compared with methods such as cooling the concrete with water or post-treatment. ECLIPS is currently not sufficiently well developed to be used on the infrastructure of RWS or other road managers within the next few years. We recommend waiting until the current round of planned field tests has been completed and then deciding whether a pilot on behalf of RWS would offer sufficient added value.’[7]

[7] ‘Infravation Business Case’ by Arno Willems, August 2018

2.4 FASSTbridge

The focus of the FASSTbridge project was on finding **fast and effective solutions for steel bridges' life-time extension**.

It aimed to drastically reduce the economic and environmental costs of ownership of the steel bridges stock in Europe and the USA by providing a reliable preventive, cost-effective, and sustainable solution for steel bridge life-time extension.

The FASSTbridge solution stands on two pillars:

1 FASSTbridge methodology: an easy-to-apply methodology (fatigue life-time assessment, design, execution and maintenance guideline) to prevent the evolution of irreversible fatigue derived problems at a pre-failure scenario, and
2 FASSTbridge strengthening system: a reliable, cost-effective CFRP strengthening system to preventively extend lifetime of steel bridges.

The solution involves the use of adhesively-bonded carbon-Fibre-reinforced polymers (CFRP) to retrofit aging steel bridges to extend their fatigue life. This includes a two-component epoxy-polyurethane adhesive developed by COLLANTI CONCORDE, which is characterised by strong flexibility and a good adhesiveness on various materials. It also includes a sensor technology that takes a direct measurement between the steel infrastructure and the CFRP to capture any debonding in real time.

The adhesive solution has been developed specifically for the application in bridges (steel/carbon) but the adhesive could also be used for metal to metal bonding applications in other sectors such automotive, as well as naval. With additional testing, it may also prove applicable to high load applications (e.g. roofing, refurbishments).

<u>The end user of the technology and user requirements</u>

This solution will be attractive to bridge manager-owners/contractors/engineering firms in Europe and America. The end user of the adhesive is the manufacturer of the commercial system (adhesive + CFRP). The adhesive cannot be sold by itself because is optimised and tested to EPSILON CFRP.

<u>Technology readiness level</u>

The TRL review panel noted that this field test meets the criteria for TRL 6 (Prototype Tested in a Relevant Environment) but that additional testing in a wider range of environmental conditions may be beneficial.

<u>Next steps</u>

The technology utilises high modulus and non-pre-stressed CFRP plates. It would be beneficial to successfully design a retrofit using pre-stressed and standard modulus CFRP.

Standardisation activities for certifying the system, including CE marking is required, which could be undertaken via an ETA: European Technical Agreement. All the testing required for technology certification (this will depend on the requirement of the certification establishment) have been performed.

Additional lab testing on the debonding sensor is planned. Similarly, the technology should be implemented on additional bridges for demonstration and monitoring.

Rijkswaterstaat business case assessment

‘FASSTbridge offers a solution to a specific problem, with the focus on reducing fatigue stress in the bottom flanges of steel beams (as the main load-bearing structure) and is therefore of limited use for the fatigue problems affecting RWS steel bridges. However, with a few adjustments the experts do believe this has potential for use in the Netherlands. We recommend testing specific applications such as these in a pilot.’[8]

[8] ‘Infravation Business Case’ by Arno Willems, August 2018

2.5 HEALROAD

The focus of the HEALROAD project was on **induction heating asphalt mixes to increase road durability and reduce maintenance costs and disruptions**.

The induction heating of asphalt mixtures is a preventive and non-intrusive maintenance technique used to accelerate the self-healing properties of road pavements, reducing it from the days currently needed to heal micro-cracks to a few seconds. Preliminary tests have shown that the lifetime of asphalt pavements could be potentially extended by 30% with every healing treatment.

The objective of the HEALROAD project was to underpin the industrialisation of this technology. The aim was to develop, optimise, and demonstrate asphalt mixtures that can be induction heated. It was expected that this technique would postpone for several years the need for major maintenance of wearing courses, ensuring best value for money and improving resource efficiency.

Asphalt mixtures incorporating metallic particles are susceptible to being heated by induction. Preventive maintenance is applied to the asphalt mixture by induction heating with the aim of closing microcracking before effective cracks (i.e. cracks that cannot be repaired with induction) appear in the material.

A manual for the design and manufacturing of these mixes in the asphalt plan was prepared in the project. The technical specifications of the metallic particles that were tested and assessed are also available.

A real-scale test implementation of the technology was conducted at BASt, involving all components of the system, i.e. manufacturing in real plant, construction by conventional methods, damage, and on-site healing.

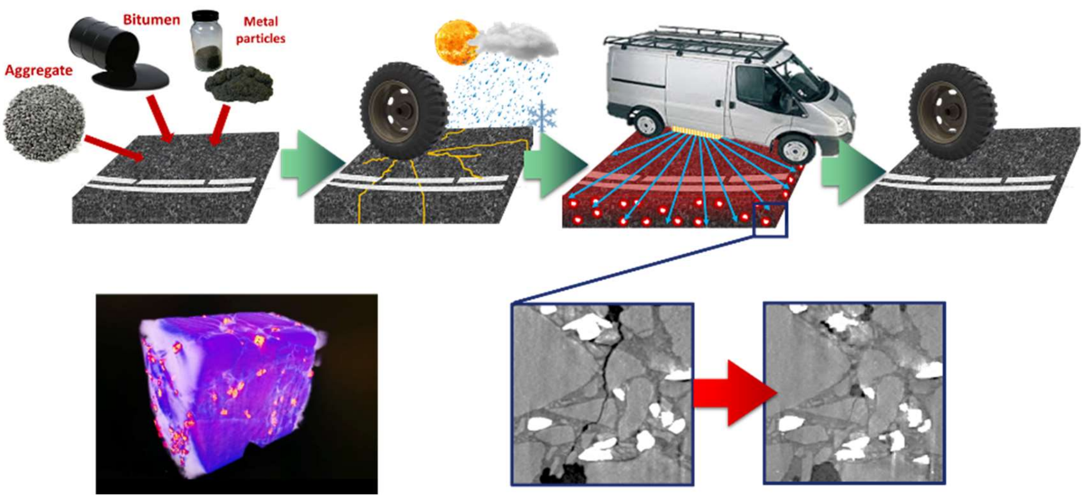

Figure 7: the HEALROAD concept

The end user of the technology and user requirements

Road authorities (via contractors and maintenance teams) would deploy this pavement technology.

Technology readiness level

The TRL panel agreed that the technology had a reached a TRL of between 5 (Integrated components demonstrated in a laboratory environment) and 6 (Prototype demonstrated in relevant environment). The panel agreed that the technology satisfied all of the requirements indicated by a TRL 5 and most requirements of a TRL 6.

Next steps

Several challenges remain. These include:
- the optimum moment for the application of induction treatment, including the optimal surface condition/PCI marks/visual cracks on the surface;
- defining the extension of road durability that is achieved under field condition;
- defining number of times that the asphalt mixture can be healed effectively and efficiently (this is being assessed in the project);
- testing on a full-scale induction machine. Currently, industrial equipment is available that can be used on actual roads. However, the size of the coil and the application time should be improved;
- compatibility of the metallic particles with elastomeric modified binders such as rubber modified bitumen;
- testing on heavy traffic environments or anomalous conditions (i.e. construction in extreme weather conditions).

Rijkswaterstaat business case assessment

‘HEALROAD is at an advanced stage of development and is ready for testing in practice. However, the fact that from a practical point of view, it is not yet possible to use HEALROAD on large stretches of asphalt rules out introducing it on a large scale in the short term. The tests in the Netherlands and Germany are not yet providing enough usable results. Therefore, more testing will be needed to obtain a more reliable picture of its effect before field testing under motorway conditions can get under way.

We recommend testing HEALROAD on small, heavy-traffic sections of roads to begin with—preferably on a tight bend or at expansion joints—for the aspects of life span extension, availability of steel fibres and impact on the environment. These tests can be carried out with existing resources. Testing options include two expansion joints on the A12 Arnhem-IJssellaan and a tight bend near the A59. The results can be used to determine whether HEALROAD is only suitable for specific high traffic stretches of road or whether it could also be rolled out over longer stretches of motorway. Finally, we recommend carrying out a quantitative LCC analysis.’[9]

[9] ‘Infravation Business Case’ by Arno Willems, August 2018

2.6 SEACON

The focus of the SEACON project was on **sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement**.

Its objective was to analyse and demonstrate the use of chloride-contaminated concrete for the construction of durable concrete infrastructure, such as bridges. Chloride-contaminated concrete is concrete produced with seawater rather than fresh water.

Several technologies enable this innovation, perhaps most notably the use of corrosion-resistant composites as an alternative to steel in sustainably produced reinforced concrete structures. These novel bridge components offer functional advantages when compared with conventional steel reinforced components; most notably, they may be less susceptible to corrosion than steel reinforcements.

A related objective of the SEACON project was to investigate the performance of recycled aggregates in chloride-contaminated concrete infrastructures, increasing the sustainability of concrete production. The SEACON-developed chloride contaminated concrete mixes have a reduced environmental impact compared with freshwater concrete mixes that use new aggregate. In addition to conducting life-cycle assessment of SEACON concrete mixes, the research team also participated in two real-size demonstration projects: one in conjunction with Florida DOT (FDOT) to provide concrete for bulkhead caps at the Halls River Bridge in Citrus County, Florida; and, another one in conjunction with Pavimental to construct a culvert along the A1 motorway in Pontenure, Piacenza, Italy. These projects will provide the research team with the opportunity for long-term performance monitoring.

Figure 8: Generic image of bridge substructure elements

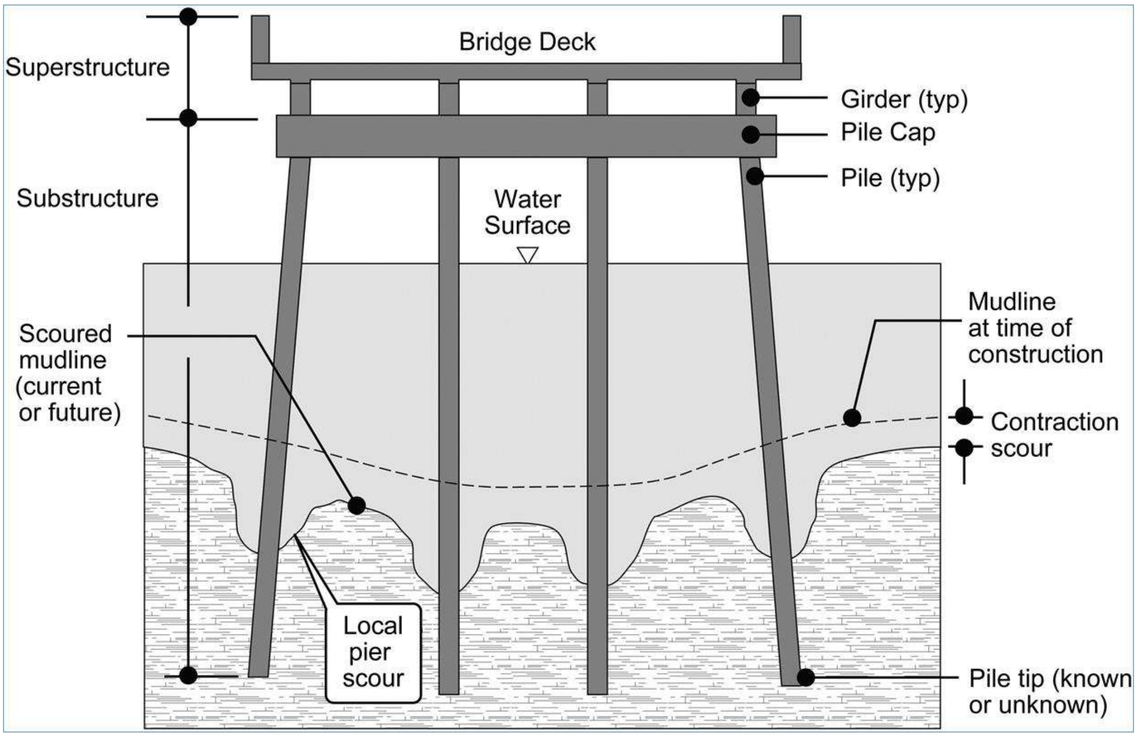

Figure 9: Plan view of the bulkhead cap made with SEACON concrete (courtesy of SEACON)

<u>Technology readiness level</u>

Considering the critical technology developed and advanced in the SEACON project, the focus was on the specifications and development of chloride contaminated concrete. The panel determined a TRL of 3 (Proof of Concept: Components validated in laboratory environment).

<u>Next steps</u>

Additional structured testing on concrete mix design (including the ingredients and amounts of each ingredient) based on the level of chloride contamination introduced to the mix would be necessary to meet the TRL 4 requirement.

Additional testing may be necessary to better characterise the interaction between GFRP rebar and saltwater-contaminated concrete and/or concrete produced with recycled aggregates. This testing would be necessary to meet the TRL 5 requirement.

<u>Rijkswaterstaat business case assessment</u>

‘SEACON is a potentially interesting application for areas in which freshwater is scarce. The innovation is at an advanced stage and is ready for commercial use. We therefore recommend investigating its potential for use on the Caribbean islands, especially on St Maarten, Saba and St Eustatius, since these islands were badly affected by Hurricane Irma earlier this year and a lot of reconstruction has to take place in a short space of time.

However, SEACON does not seem of interest for areas with adequate supplies of freshwater, since the initial cost of using non-corrosive reinforcement is higher than for steel. According to the SEACON LCC analysis, this is more than offset by the longer life span and the fact that no regular major maintenance is needed, but various assumptions and calculations in this LCC analysis are poorly substantiated and sometimes even incorrect. For this reason, it is not possible to come to a satisfactory conclusion on the SEACON LCC. In addition, not enough is known as yet about the long-term effects on its structural safety. Finally, in Europe this innovation runs up against legislation and regulations that do not allow the chloride content in concrete to exceed 0.4% (m/m) of the cement content.'[10]

[10] 'Infravation Business Case' by Arno Willems, August 2018

2.7 SeeBridge

The focus of the SeeBridge (Semantic Enrichment Engine for Bridges) project was on the **automated compilation of semantically rich BIM models of bridges**.

It targeted the development of a comprehensive new tool for the rapid and intelligent survey and assessment of bridges. In the SeeBridge approach, various advanced remote sensing technologies, including terrestrial laser scanning, video, and photogrammetry were used to rapidly and accurately capture the state of a bridge.

The SeeBridge process is comprised of the following sections ordered chronologically:

1) Information Delivery Manual (IDM) and Model View Definition (MVD): The IDM specifies a methodology that unites the flow of construction processes within the specification of the information required. The MVD defines a subset of the IFC model and it is complete for girder bridges and all defect types.
2) Point Cloud Data Acquisition: Obtain detailed spatial raw data (3D point clouds), using high density surveying technologies which include laser scanning (Lidar), Trimble MX7 (mobile mapping system), and photogrammetry (a 1080p video camera). The data obtained was further processed to produce spatial raw 3D point clouds. This was tested on multiple bridges.
3) 3D Geometry Reconstruction: this system utilizes data obtained from the point cloud phase and converts the same into a workable 3D BIM model. This was tested on multiple bridges.
4) Semantic Enrichment: Here, the bridge model obtained from the 3D reconstruction phase is enriched to incorporate meaningful information to the IFC model, including grid creation, element classification, geometry recreation and grouping. SeeBIM 2.0 software uses the rulesets and automatically performs the desired operation on individual elements, as well as the entire model. This was tested on multiple bridges.
5) Damage Detection and Modelling: The models developed in the 3D reconstruction phase can be further enriched with information in the semantic enrichment phase, adding structurally relevant information vital for inspection, such as cracks. This component has been tested on one bridge and needs additional development.

<u>The end user of the technology</u>

Asset owners are the intended end user. Most currently-used bridge management systems do not yet use IFC files—which are the standard BIM format—for 3D models.

<u>Technology readiness level</u>

The TRL panel agreed that the technology had a reached between a TRL of between 5 (Integrated components demonstrated in a laboratory environment) and 6 (Prototype demonstrated in relevant environment), satisfying all of the requirements indicated by a TRL 5 and almost all requirements of a TRL 6.

Next steps

Two additional types of testing will need to be performed:

1. The SeeBridge engine will need to be tested on other types of bridges.
2. The 3D reconstruction process should be tested on a wider range of bridges and for more conditions; some bridge architectural features and occlusions may create issues that additional testing will.

Rijkswaterstaat business case assessment

‘This development is of great importance and is fully in line with global developments in digitalisation and robotization. From this point of view, the innovation fits in perfectly with RWS policy. However, there are still some major technological hurdles to be overcome before the innovation can be considered for widespread use at RWS (currently TRL 5). The innovation is so interesting that we recommend monitoring developments closely and, if possible, supporting them with one or more pilots.’[11]

[11] ‘Infravation Business Case’ by Arno Willems, August 2018

2.8 SHAPE

The focus of the SHAPE project was on **predicting strength changes in bridges from frequency data safety, hazard, and poly-harmonic evaluation**.

SHAPE is designed to be attached to a road bridge to monitor the vibration of the bridge over time. The SHAPE project sought to develop a cloud-based approach in order to provide a centralised data management and analysis system for the long-term monitoring of these structures. The effort required to develop the infrastructure to support this type of monitoring, which is really an international rather than a national issue, was considered enormous and the development of the theoretical analysis required data from similar bridge types which are often scattered across several countries.

The SHAPE project developed the WinetBox, an outdoor stand-alone embedded sensing device with cloud-server management functionality, data automatic collection and presentation. Its purpose is the monitoring of the physical conditions of structural elements.

WinetBox for SHAPE is the first building block in a distributed sensor system for the early warning of critical service conditions in building and bridges. In future deployment, it will be used for the continuous monitoring of infrastructures through an automatic damage detection software.

This technology is meant to be deployed in the field (external or even harsh environment) for the physical monitoring of major outdoor structures (e.g. bridges, buildings).

Preliminary tests have been conducted on the full system (box, device, driving board, energy supply circuit) in the Winet Laboratory. Then, a functionality test was performed outdoors on a bridge model but in a laboratory setting.

Finally, three complete devices were deployed on three real bridges in harsh environmental conditions and geometrical configurations. These devices demonstrated their robustness through continuous acquisition and crash recovery over the course of more than two months. The functionality test was expected to continue for another 6 months before the final presentation of the acquisition data.

The demonstration scale and settings of this technology exactly match the environmental conditions of the envisioned final deployment. The technology is ready to use and has been tested in the right field of application.

The firmware of the application has been successfully simulated and debugged and the system has been tested in the envisioned field of application. The theoretical framework for the damage detection engine is under development and will be presented in international journals as it will be demonstrated with experiments.

This technology will allow for remote monitoring of structures with real time evaluation of the safety conditions.

The end user of the technology

The end user for the technology will be bridge owners, possibly via consulting engineers or technicians installing and monitoring the technology.

Technology readiness level

The feasibility of a stand-alone device at TRL level 7 has been demonstrated.

Next steps

From the point of view of device implementation on bridge sites, the technology is mature and ready to use. Some updates could reduce the cost and increase the efficiency of the boxes. At this implementation stage the device needs some advancements in terms of the redundancy of the sensors (multiple sensors connected to a box), speed of detection of a change in the physical parameters (real time feature extraction), connection of the changes with position, and intensity of the structural defects (early warning system).

From the point of view of the damage detection in the data streams, many new algorithms and procedures need a careful theoretical deepening and a real on-site testing.

Rijkswaterstaat business case assessment

‘SHAPE has potential as an innovation that contributes to increasing the reliability, availability and safety of the infrastructure and reducing lifetime costs. The innovation also fits in with the global trend and RWS’s policy of digitalisation and robotization and risk-based management and maintenance. The application is affordable, scalable and relatively easy to adapt to future developments and requirements.

The hardware (the SHAPE Box) is currently available but the necessary software for interpreting the measurement data in terms of existing or potential damage will still take many years to develop. It is even questionable to what extent damage will be able to be distinguished from regular use in a measurable and interpretable way in the form of deviating frequencies. There are therefore currently too many uncertainties for RWS or other road managers to be able to use it in the short term.

In view of its potential, however, we recommend continuing to monitor the project and supporting it with a (modest) financial contribution or by making one or more bridges available for field testing so that the technology can be further refined and the LCC analysis can be produced. After all, a thorough quantitative LCC analysis must be carried out first before RWS can apply this in practice.’[12]

[12] ‘Infravation Business Case’ by Arno Willems, August 2018

2.9 SUREBridge

The focus of the SUREBridge project was on the **sustainable refurbishment of existing bridges**.

It aimed to realise an innovative and holistic refurbishment approach (method, technology, and calculation tool) using fibre-reinforced polymer (FRP) materials to perform bridge maintenance including repair, strengthening, and refurbishment actions in the most effective and efficient way, in the shortest possible time, with the most efficient, sustainable use of resources, and with minimum possible disturbance and disruption for the environment and road users.

What is the technology?

The purpose of the SUREBridge project was to provide a cost-efficient and structurally effective tool for strengthening and repairing concrete bridge structures. The SUREBridge project developed a concept for strengthening and repairing deteriorated concrete bridges using composite materials.

Bonding fibre-reinforced composite materials, known as FRPs, has been proven to be an effective and cost-efficient solution for upgrading existing bridge structures. FRPs have been in use since the 1970s, and since then, thousands of bridges around the world have been upgraded using this technology. The effectiveness of FRP bonding systems, however, can be improved using the latest advancements, such as bonded pre-stressed carbon FRP laminates, to enhance the bending capacity of flexural elements in bridges. Pre-stressed CFRP laminates present technical difficulties, such as anchorage complications and cost. In 2016, the cost for application of unit length of such laminates was about €600.

SUREBridge has developed an innovative method for the application of pre-stressed CFRP which eliminates the need for mechanical anchorage and lowers the cost of application. Currently, the cost for the application of a pre-stressed laminate using SUREBridge technology (including labour, and excluding the CFRP laminate cost, which is about €20–50/m) is €1,400 per laminate, regardless of the length. This means that for a 10-m-long laminate, existing solutions on the market cost about €6,000. The SUREBridge solution, on the other hand, costs between €1,600 and €1,900.

SUREBridge takes advantage of glass FRP deck panels, a technology that has been used in the construction industry for the past 20 years. GFRP deck elements are widely used in rehabilitation projects, sometimes as a replacement for existing deteriorated concrete decks.

In many old bridges, even in those categorised as structurally obsolete, there is still a lot of hidden material capacity. We know that in the worst case, concrete has at least 40% of its original capacity, which goes directly to landfill in the case of bridge re-construction. The SUREBridge project, using the effective pre-stressed CFRP strengthening laminates and heavy duty, tailor-made GFRP panels, put forward a solution that helps to restore many old bridges and give them a new lease of life.

The technology consists of bonding pre-stressed CFRP laminates to the bottom side of flexural elements such as decks and girders using an epoxy adhesive and bonding a tailor-made GFRP deck panel using a cement-based mortar on top of the existing concrete deck, thereby providing a substantial increase in load bearing capacity.

Primarily in bridge structures, especially those with severe damage and a superstructure in bad condition, the technology will address the problem of a lack of flexural and shear capacity. This technology supports and strengthens deteriorated concrete bridges with a lack of load bearing capacity. Material deterioration in bridges face a demand for ever-increasing axle loads. This has pushed many existing bridges to be classified as obsolete or inefficient, necessitating major upgrading and rehabilitations.

The system is composed of two sub-systems:

a) a tailor-made FRP decking system to be attached on top of the existing concrete deck, acting mainly as compression reinforcement and a protection element on the road surface. In certain circumstances, the FRP deck can be wider than the existing bridge and be used for bridge widening purposes;
b) a novel FRP strengthening system that takes advantage of pre-stressed carbon fibre-reinforced polymer (CFRP) laminates. The new system, unlike conventional pre-stressed FPR strengthening systems, does not need mechanical anchorage of the strengthening laminate and hence, provides a more efficient, durable and cost-effective solution that can be applied in a reasonably short time.

Both sub-systems have been scientifically verified and are commercially in use.

Components of SUREBridge are already being piloted in the real world. The technology of tailor-made GFRP deck systems used by FiberCore Europe has been under development and verification for the past ten years. SUREBridge prototypes were tested in a realistic environment outside of the laboratory at two different road bridges (Nossan Bridge and Gruvvagen Bridge) using both the CFRP laminate as well as the GFRP deck.

<u>The end user of the technology</u>

Technology end users include a wide range of bridge owners, from local municipalities to national transport administrations. The high-level end user requirements for the developed technology were drafted at the beginning of this project and the priorities were identified as:
a) minimum disruption of the traffic due to maintenance work,
b) sustainability and minimum carbon footprint, and
c) cost efficiency (in connection with minimum required future inspection and maintenance).

<u>Technology readiness level</u>

The expert panel responsible for assessing the TRL concluded that the CFRP laminate technology was currently at TRL 5. The second component, the GFRP deck, was assessed as having a TRL of between 4 (Components validated in laboratory environment) and 5 (Integrated components demonstrated in a laboratory environment).

<u>Next steps</u>

The sub-systems of the proposed technology are already in use and have proven their use in practice. The team we will re-calibrate the design models and the software tool after performing the tests and analysing the results to determine what, if any, further studies are required.

The research team will need to work out a practical way to deal with the necessary splices in GFRP deck panels. The connection of the panels, e.g. in-situ bonding, is one of the challenges to overcome. Connection of the railings to the FRP deck, in case of widening the existing deck intended as carriageway, is another challenge that needs to be addressed in corresponding applications.

Rijkswaterstaat business case assessment

‘From a technical point of view, SureBridge is a well-developed concept that is more or less ready for commercial use. Given the large number of bridges that need replacing, SureBridge is a very interesting option for both RWS and other road managers. However, many questions about the long-term use and performance of the solution still remain. We suggest testing it on smaller bridges first before using it on larger RWS bridges.’[13]

[13] ‘Infravation Business Case’ by Arno Willems, August 2018

3 Exploitation and implementation

A key aspect of Infravation is that all projects sought to develop technologies that can be directly applied by infrastructure owners and operators and in most cases involve commercially viable products that can be taken to market with varying levels of work.

The collaboration between Europe, Israel, and the US was beneficial in this respect because it ensured that potential products meet the needs of both markets. The various TRL stages indicate that while some products could be placed on the market either immediately or with a small amount of further development, others require significant further work. All projects developed exploitation plans to define the product or service and its value and route to market. Moreover, long-term relationships have been developed to take the projects to market.

In some projects, the considerable support provided by certain partners involved in the project, such as the Florida and Arizona DOTs and the Communidad Madrid, have enabled access to structures, alignment with new constructions, and a direct interface with end users, thereby ensuring potential products and services meet client requirements.

Several projects have produced a range of potentially exploitable results, such as material products, processes, services, or intellectual property. In some cases, project partners assumed responsibility for or took ownership of specific business opportunities. It should also be recognised that the motivations of the partners varied: industrial partners were driven by commercial motivation to develop products or services for sale; academic partners may be more interested in acquiring the know-how and intellectual property to secure research funding.

While various partners have prepared exploitation plans, in some cases in considerable detail, these are understandably commercially confidential and cannot be replicated in this document. In any case, there are a myriad of potentially exploitable technologies and various business options to take them forward. However, section 3.1 presents an outline of what potential technologies *could* be exploited per project, and section 3.2 sets out potential business cases and market considerations.

3.1 Technologies by project

FASSTbridge
- Strengthening system – adhesive plus CFRP plus coating
- Bi-component epoxy-polyurethane adhesive

AlterPave
- Asphalt product and bio-rejuvenator – product
- AlterPave QR tool

BioRePavation
- New design mixes
- Replacement of petroleum binder with alternative

ECLIPS
- Detailed characterisation of PCMs
- Alternative delivery method for PCMs (microencapsulated in silica shell – lower TRL)

HEALROAD
- Asphalt mixtures incorporating metallic particles heated by induction to close microcracks before effective cracks develop
- Induction heating equipment

SeeBridge
- Inspection and survey tool
- 3D BIM model and services around monitoring and assessment on behalf of bridge owners

SUREBridge
- FRP decking system attached on top of the existing concrete deck, to reinforce and protect road surface. Can also be used for bridge widening
- Novel FRP strengthening system taking advantage of pre-stressed carbon fibre-reinforced polymer (CFRP) laminates, without the need for mechanical anchorage

SEACON
- Corrosion-resistant composite reinforcement in place of steel
- Investigation of recycled aggregates in chloride-contaminated concrete infrastructures

SHAPE
- Embedded sensor device for bridge monitoring
- Cloud-based data management and analysis system

3.2 Business cases and considerations

Certain projects have prepared business cases exploring options for the commercial exploitation of the technologies developed. While these are confidential and available only to the project teams, some of the options for achieving commercial exploitation of these technologies are presented below.

Use for further research

For some technologies at a lower TRL there will be the requirement to undertake further research to raise the TRL in the process of developing a viable product. Depending on the innovation, there are a range of options for this to be funded, such as further research contracts, internal development funding, raising equity through shares of the potential future business, venture capital or long-term loans.

Developing and selling own products/services

Certain project partners have developed products or services that are close to market, such as the bridge monitoring sensors developed in the SHAPE project. These could be directly marketed to end users.

Spin-off activities

While this could be relevant to any organisation, typically, universities or research institutes may develop a product or service that is marketed and sold through a dedicated spin-off company. There are instances of industrial partners also taking this route for a technology or service developed that has an application in another sector that does not fit the company's core business.

Cooperation agreement/joint ventures

Technologies developed between two organisations can be taken forward and marketed via a cooperation agreement, or more formally through a dedicated joint venture.

Selling IP rights/selling the (IP based) business/licensing IP rights

In this scenario, a company or academic institute either sells the intellectual property for another company to take forward for a one-off payment or could sell a specific business that has developed IP. A variation on this is license the IP rights to another company to sell the product or service in return for regular royalty payments. While the sale of IP or a business, tends to be a one-off transaction, in the case for licensing there can be conditions on geographic region and timescale of the agreement, so for example different licenses can be agreed for individual markets, or at a continent, country, state, or regional level.

Standardisation activities (new standards/ongoing procedures)

In some cases, there can be business opportunities in developing a new technology that can be the reference technology for future standards, in being paid consultancy fees to prepare new or update existing standards.

As well as considering the mechanism to exploit the results from the options above or other means, there is a requirement for consideration of market conditions and timing as outlined below. This is particularly relevant if a project has developed a number of potential opportunities for understanding which one to prioritise, which might not be the most obvious one originally envisaged.

Customer – who and what benefits does product bring?

The primary consideration is whether someone will pay for the product or service being developed. Who would the end-user be (these have been identified per product) and what benefit does the product bring or what problem does it solve?

Market site, time to market, and market trends

Considerations here include the size of the market, such as whether the market is large or niche, and if it is a niche product, is the market crowded with competitors. Another factor will be how long it will take to undertake further development to bring it to market, particularly if by being first to market will give a dominant position; alternatively, should there be a lengthy process for bringing the product to market, a competitor might have the dominant position. Finally, the market trends need to be considered, for example; if the market trend is or will be in the future based on non-destructive and non-invasive testing, does the product meet this and ideally would it be an early entrant to the market. Alternatively, is the product or service something that could be obsolete in a few years.

Achievable price for product/services

Quite simply how much someone would be willing to pay for the product or service, and whether the profit margin was attractive or not. This is particularly important in considering which of a number of options might bring the best return. This is particularly relevant if a technology requires further development and testing before it can be brought to market: will there be a return on that investment and in what timescale?

Competitors and competing products

It is necessary to consider both competitors and competing products to see how your product or service fits. Understanding who the competitors are in the market, what is there market share, location, sector and sales and distribution network, and understanding your strengths and weaknesses in comparison.

You also need to understand the strengths and weaknesses, features and benefits in relation to competing products, and why a customer would buy from you rather than anyone else.

Further costs to bring to market (e.g. patents, additional tests, certification)

As indicated above, if there is a considerable time and/or financial cost in bringing a technology to market, then there needs to be some degree of certainty that these costs can be recovered and that the technology will become profitable in an acceptable timescale. Even a technology at a high TRL can incur significant costs to undergo certification or patents, and consideration needs to be given as to whether the cost of the patent will be worth the protection it might afford.

Linked to this is IPR and protection of results. Can they be protected and what value would they have, or would a better option be to bring the product to market quickly and gain market position.

Internal and external partners and distribution of potential profits

Where there are partners, there needs to be a mechanism established to ensure that the profits are correctly accounted for and payments distributed accordingly.

Rijkswaterstaat business case assessment (for all nine projects)

The Rijkswaterstaat business case assessment of all nine Infravation projects concluded that 'all the projects contain relevant developments that have potential for use at the European or even global level. However, partly because the Netherlands is already one of the front runners with regard to various applications, some of the developments are of less relevance to Rijkswaterstaat. Only a small number of projects seems to be of interest to it in the medium or even the short term.'[14]

[14] Infravation Business Case' by Arno Willems, August 2018

4 Dissemination

Dissemination was undertaken at both programme level and individual project level, with each project having a website and dissemination plan. Many projects held joint workshops during the project and joint dissemination events. The Infravation programme also held a number of promotional events. Significant technical press coverage was secured, and numerous academic papers were submitted to peer-reviewed publications. Several innovation conferences took place, including the final project conference, which was held on 4–5 October 2018.

5 Conclusions

Infravation successfully addressed the main challenges of formulating and implementing an R&D&I programme at intercontinental level. Any initial difficulties and constraints encountered in the early stages related to the management and organisation of agreements (administrative, intellectual property, long timeline between political declaration and concrete agreement, and others) but were overcome. In view of this success, Infravation provides both a blueprint framework for future initiatives that would make it possible to substantially reduce the overheads of future programmes and a flexible tool for research funding.

The common pot approach, which involved funders from Europe, Israel, and the US as well as a top-up contribution from the EC, overcame any potential individual national interests to award projects on the basis of their scientific, technical, and managerial merits. Above all, nine high-quality projects were selected on the basis of an assessment of their ability to solve the technical challenges faced by infrastructure owners.

All nine projects successfully delivered technological innovation that will bring benefits to transport owners and operators and society in general. Exploitation plans and individual business cases have been prepared for the commercial deployment and exploitation of technologies.

The support of road authorities was instrumental in bringing added value to the programme and scientific outputs.

As a whole, the programme received significant attention within the research community. Each project also organised numerous—sometimes joint—dissemination activities. Numerous papers have been submitted by the academic partners.

From a CEDR perspective:

- Infravation was a valuable pilot exercise especially in terms of the common pot funding approach with the United States in CEDR-defined research areas.
- While no recommendations on the application of advanced materials, systems, and techniques in road infrastructure were made specifically to CEDR as a whole, information was made available to NRAs via the extensive dissemination work carried out by the individual projects.
- In response to challenges experienced in the field of international cooperation, CEDR developed towards the end of the programme clear rules on co-financing with external bodies and international cooperation. These rules strengthen the CEDR Transnational Research Programme. This ensures that NRAs and other public bodies funding research can attract the best expertise at global level to address European challenges.

Building on the accumulated experience of the Infravation programme, a follow-up programme with a bigger funding volume could be considered in the future, albeit with clear limitations on the overheads and inefficiencies imposed by EC (ERA-NET Cofund) requirements. Consideration has been given within CEDR's WG Innovation to adopting the lessons learned in both Infravation and ERA-NET ROAD to enable EC funding for dissemination and communication activities only.

6 Moving forward after Infravation

Following discussion within WG Innovation in September 2017, the CEDR Governing Board decided to launch a proposal for EC funding (Coordination and Support Action (CSA)) to support CEDR's innovation programme. It invited Finland, the Netherlands, and Denmark to decide the management.[15]

In November of the same year, WG Innovation set up a reflection group to reflect on the interests of CEDR member organisations regarding the CSA and to decide on the further management of the CSA proposal. It succeeded in establishing common ground for the preparations of the CSA.

In preparation for TRB 2018, Peter Wilbers (RWS), Richard van der Elburg (RWS), Gert von der Ahé (Denmark, CEDR EB), Steve Philips (CEDR Secretary General), Pieter de Winne (Flanders, Chair WGI) and Ronan Cunniffe (CEDR Research Coordinator) discussed the various aspects of the CSA. **Based**, among other things, **on the experience gained with Infravation**, it was agreed that[16]

- CEDR support for the CSA depends on the **added value for CEDR in the support for WG Innovation activities and taking forward cooperation with other modes under the 'CEDR approach to the implementation of innovation'**. This includes strategic stakeholder engagement, dissemination, implementation, deployment, and training. CEDR support is also contingent on **the application of relevant CEDR rules**.
- In terms of the CSA, as probably the largest stakeholder, **preferably 50% of the CSA beneficiaries (consortium partners), should be CEDR members. Any strategic issues related to CEDR–EC relations should be approved by the CEDR GB**.
- **Stakeholder engagement can help define CEDR's 2019 and 2020 calls and dissemination can take into account projects that are already up and running**.
- The common goal of the CSA is **to take cross border, transnational, transatlantic research to a higher level and make things more professional**. It should also address the **allocation of research needs to the proper platforms**.
- **Preparation and optimisation of US involvement and money flows can be part of the CSA**, e.g. current payments through FEHRL caused a lot of issues. Denmark will usefully develop the principles for US payment in the coming years.
- **The Infravation lessons learned (ERA-LEARN case study) should be incorporated into the CSA**.

A project called infra4Dfuture ('Infrastructure Innovation for the Future') was subsequently awarded a grant by the EC under the Horizon2020 programme. The project is supported by CEDR and EIM and involves more than 12 CEDR members. The aim is to 'develop a demand-driven overarching strategy and coordination mechanism for the modernization of transport infrastructure including a shared strategic vision on future infrastructure capabilities and common pathways for innovation development and implementation.'[17]

---

[15] GB decision GB29/7 at the Madrid meeting, 5 October 2017
[16] CEDR 'Memo in preparation for the TRB 2018 and further'
[17] infra4Dfuture website (http://www.i4df.eu/index.php)

CEDR Contractor Report 2019-04

Infravation Summary Report

Ref: CR2019-04
ISBN: 979-10-93321-52-3

Conference of European Directors of Roads
Avenue d'Auderghem 22-28
1040 Brussels, Belgium

Tel: +32 2771 2478
Email: information@cedr.eu
Website: http://www.cedr.eu

9791093321523