BISON

BIODIVERSITY AND INFRASTRUCTURE SYNERGIES AND OPPORTUNITIES FOR EUROPEAN TRANSPORT NETWORKS

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Deliverable D4.2

Strategic research action programme

"Strategic Research Agenda: the research side of the BISON SRDA"

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EXECUTIVE SUMMARY

The BISON project is led by a consortium of 39 European members and associated countries. It aims to tackle the integration of biodiversity with the development of infrastructure, including roads, railways, waterways, airports, harbours, or energy transport networks.

The BISON project will meet the above aim through the following objectives:

- Identify future research and innovation needs for a better integration of biodiversity with infrastructure.
- Identify the construction, maintenance and inspection methods and materials which are long-lasting and resilient and can be used by different transport modes to mitigate pressure on biodiversity.
- Support European Member States to fulfil their international commitments by engaging all stakeholders into biodiversity mainstreaming for infrastructure planning and development.
- Strengthen European Member States' leadership in sustainability, by showing the way to other countries, including developing countries.

This deliverable is produced in the context of WP4 – Towards a Research Agenda for Europe. The objective of WP4 is to produce the research side of the Strategic Research and Deployment Agenda (SRDA) that can be endorsed and successfully rolled out by the national transport infrastructure authorities and the public innovation programme owners, representing the environmental and social needs and requirements for infrastructure innovation with a particular focus on biodiversity. In order to pave the way towards future relevant innovative solutions and developing alternatives for more biodiversity-friendly transport infrastructures, WP4 methodology builds notably on inputs from industry stakeholders, transport authorities, the research community as well as environmental agencies.

Deliverable D4.2 – Strategic research action programme, is the final deliverable of WP4 and constitutes the strategic research agenda (SRA) for a better integration of biodiversity with infrastructure in Europe.

The document begins by presenting the three-step methodology adopted throughout the project to develop the SRA. To begin with, a summary of the most important elements (inputs/outputs) of step 1 is provided: online consultation, document survey, expectations; proposals. This step is extensively presented in Deliverable 4.1. Then the process of step 2 (Analysis and classification of issues) is presented. The result of this step constituted Milestone 4.1 (Broad detailed overview of research needs). Lastly step 3 (Prioritization of research actions) is presented, with its analysis of potential issues for research (PIRs), the emergence of 15 themes (indicators of the nature - and degree - of questioning of stakeholders), the prioritization parameters (maturity reference system: TRL and SRL; relevance; research effort) and the long process of progressive refinement of research actions (RA) through several consultations of stakeholder.

The result of the whole process is presented in Section 3, with the list of 92 research actions, ranked into 14 major problematics. The wording of research actions follows the format WHAT (Action) FOR WHAT (Objective). For each of them are provided details on the time horizon it should be completed (5, 10, 15 or more years), the transport infrastructure concerned (roads, railways, waterways, power lines, pipelines, airports, harbours), the life stages concerned (planning, design, construction, adapting, operating, decommissioning), the themes it is related to (from one to three within the list of 15), the stakes of the original call (H2020-MG-2020) of the project (biodiversity, climate change, social change, changing demand, technology, digitalisation).

The analysis of themes shows the importance of the questions specifically posed to biodiversity by transport infrastructures (45% of the total). However, research actions related to improving the general process of transport infrastructure development together account for 25% of themes and the theme “Reduction measures” alone still represents 16% of the occurrence of themes. Almost all research actions regard the road and railway sectors (97% and 96%), then airports and waterways (88% and 87%), then harbours (80%), powerlines (78%) and pipelines (74%). As the vast majority of research actions are not specific to a single type of infrastructure, this makes possible significant cross-fertilization of knowledge between the different transportation sectors.

Operating is the most considered life stage (91%) which attests to the progress still necessary for this stage despite “historical” in transport ecology. The same applies for Design (79%). Adapting of pre-existing infrastructures now raise also many questions (82%). Although fewer in number, research actions relating to Planning (51%) and Decommissioning (49%) mark a renewal of research questions, notably through integrated planning and rewilding respectively. The Construction stage raises fewer questions (36%) but following the life cycle analysis approach, it includes distant effects on biodiversity due to material supply for the creation of infrastructures.

The implementation of three tools to improve the effectiveness of research in transport ecology in Europe is proposed: a data collection system from the mandatory monitoring of transport infrastructures; the development of full-scale experimentation projects to test hypotheses and solutions; a network of long-term study areas across Europe.

To anticipate the actual implementation of research actions by the EU and member states, a reflection has been developed on the research environment today with respect to the topic addressed by BISON and in view of its future support by various sources of funding. European but also national, transnational or cross-industry levels have been regarded, which open on several possible avenues.

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This regards first all the members of WP4, and in particular those persons who took on essential “sub-tasks”, from the start until the end of the WP process: Peter Mederly (UKF), Jiří Jedlička (CDV), Alix Aliaga (Egis), Catherine de Roincé (UPGE), Michel Dauvergne (UGE), Ondine Deyrieux (OFB) and Nicolas Hette-Tronquart (OFB). This regards also many members of other work-packages of BISON (WP2, 3 and 5), members of the Advisory Group (M. Heiming (EIM, Belgium), E. Losos (Duke University, USA), R. Palmer (UN Environment Program), C. Cremezi (SNCF, France) and C. Steenbeck (Vejdirektorat, Denmark)) as well as experts in transport ecology external to BISON (C. Grilo (University Aveiro, Portugal), Y. Wang (Academy of Transport Sciences, China), W. Collinson (EWT, South-Africa); M. Bhardwaj (SLU, Sweden) and P. Anděl (Technical University Liberec, Czech Republic)). Lastly this regards the numerous attendees to the IENE 2022 conference workshop (community of practitioners and scientists of transport ecology) and TRA 2022 conference invited session (community of practitioners and scientists of transport systems).

The authors warmly thank all of them for their contributions.

TABLE OF ACRONYMS

Abbreviation	Meaning
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ACI Europe	Airports Council International Europe
ACLIE - EWT	African Conference for Linear Infrastructure and Ecology – Endangered Wildlife Trust
AFB	*Agence Française de la Biodiversité* / French Biodiversity Agency, France
AIVP	*Association Internationale des Villes Portuaires* / The worldwide network of port cities, France
AMPHI	Amphi International ApS, Denmark
ANET	Australasian Network for Ecology and Transportation
ASFA	*Association des Sociétés Françaises d'Autoroute* / Association of French Motorway Companies, France
ATEC	*Association pour le développement des Transports, de l'Environnement, et de la Circulation* / Association for the Development of Transport, Environment, and Traffic, France
BASt	*Bundesanstalt für Stanssenwesen* / Federal highway research institute, Germany
BISON	Biodiversity and Infrastructure Synergies and Opportunities for European transport Network
CAS	*Centre d'Analyse Stratégique* / Centre for Strategic Analysis, France
CBD	Convention of Biological Diversity, United Nations
CDV	*Centrum Dopravniho Vyzkumu* / Transport Research Centre, Czech Republic
CEDR	Conference of European Directors of Roads
CER	Community of European Railway and infrastructure companies
Cerema	*Centre d'Etudes et d'expertise sur les Risques, l'Environnement, les Mobilités et l'Aménagement* / Centre for studies and expertise on risks, the environment, mobility and development, France
CESE	*Conseil Economique Social et Environnemental* / Economic, Social and Environmental Council, France
CILB	*Club Infrastructures Linéaires et Biodiversité* / Linear Infrastructures and Biodiversity Club, France
CLLC	Center for Large Landscape Conservation, USA
CNRS	*Centre National de la Recherche Scientifique* / National Center of Scientific Research, France
CoARA	Coalition for Advancing Research Assessment
CSA	Coordination and Support Action

DGAC	*Direction Générale de l'Aviation Civile* / General Directorate of Civil Aviation, France
EARTO	European Association for Research and Technology Organisation
EBA	European Boating Association
EBRD	European Bank for Reconstruction and Development
EC	European Commission
EEA	European Environment Agency
EFIP	European Federation of Inland Ports
EGIS	*Egis Structures et Environment, France* / Structures and Environment
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIM	European Rail Infrastructure Managers
ENTSO-E	European Network of Electricity Transmission System Operators
ERA	European Railway Association
ERRAC	European Rail Research Advisory Council
ESPO	European Sea Ports Association
EU	European Union
FEHRL	Forum of European Highway Research Laboratories
FNE	*France Nature Environnement* / France Nature Environment
FPPE	Fauna Passage Poland - Environment, Poland
FRB	Fondation pour la Recherche sur la Biodiversité, France
G20	Group of 20 countries with the world's biggest economies
GEF	Global Environment Facility
GIB	Global Infrastructure Basel, Switzerland
HARMON	Harmonization of Green and Grey Infrastructure in Danube Region, Danube transnational programme
HS2	High Speed 2, UK
IAU	*Institut d'Aménagement et d'Urbanisme de la région Île-de-France* / Institute of Planning and Urbanism of the Île-de-France region, France
ICOET	International Conference on ecology and Transportation
IDRRIM	*Institut des Routes, des Rues et des Infrastructures pour la Mobilité* / Institute of Roads, Streets and Infrastructures for Mobility, France
IENE	Infrastructure and Ecology Network Europe
IFD	Innovation Fund Denmark
IFSTTAR	*Institut Français des Sciences et Technologies des Transports, de l'Aménagement et des Réseaux* / French institute of science and technology

	for transport, development and networks
IHMA	International Harbour Masters Association
IISD	International Institute for Sustainable Development
IMO	International Marine Organization
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IRSTEA	*Institut national de Recherche en Sciences et Technologies pour l'Environnement et l'Agriculture* / National Institute of Research in Science and Technology for the Environment and Agriculture, France
ISO/TC 331	International Standard Organisation / Technical Committee Biodiversity
ITS	Intelligent Transport Systems
IUCN	International Union for Conservation of Nature
MDV (MINDOP)	*Ministerstvo dopravy a výstavby* / Ministry of Transport and Construction of the Slovak Republic
MIRRI	*Ministerstvo investícií, regionálneho rozvoja a informatizácie* / Ministry of Investment, Regional Development, Slovakia
MTES	*Ministère de la Transition Ecologique et Solidaire* / Ministry of Ecological and Solidarity Transition, France
MŽP	*Ministerstvo životného prostredia* / Ministry of Environment of the Slovak Republic, Slovakia
NASA	National Aeronautics and Space Administration, USA
NCA CR	*Agentura ochrany přírody a krajiny* / Nature Conservation Agency of the Czech Republic, *ČR*
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OFB	*Office Français de la Biodiversité* / French Office for Biodiversity
PIA	*Programmme d'Investissements d'Avenir* / Future Investment Programme, France
PIANC	Permanent International Association of Navigation Congresses
PIARC	Permanent International Association of Road Congresses
RPS	Raptor Protection of Slovakia, SR
SBSTTA	Scientific, Technical and Technological Advice
SEA	Strategic Environmental Assessment
SEA-Europe	Shipyards' and Maritime Equipment Association of Europe
SNCF	*Société Nationale des Chemins de fer Français* / National Railway Company, France
ŠOP	*Štátna ochrana prírody* /State Nature Conservancy of the Slovak Republic

SR	Slovak Republic
SRA	Strategic Research Agenda
SRDA	Strategic Research and Deployment Agenda
SRIA	Strategic Research and Innovation Agenda
SRL	Societal Readiness Level
ST	Subtask
STRIA	Strategic Transport Research and Innovation Agenda
STUBA	Slovak Technical University in Bratislava (Spectra), SR
T20	Think 20 (network of think tanks from G20 countries)
TDIE	*Transport Développement Intermodalité Environnement* / Transport Development Intermodality Environment, France
TII	Transport Infrastructure Ireland
TRA	Transport Research Arena
TRB	Transportation Research Board
TRL	Technology Readiness Level
UAF&FA	*Union des Aéroports Français et Francophones Associés* / Union of French and associated French-speaking airports, France
UGE	*Université Gustave-Eiffel*, France
UIC	International Union of Railways
UKF	*Univerzita Konštantina Filozofa v Nitre* / Constantine the Philosopher University in Nitra, SR
UN WPSP	United Nations World Ports Sustainability Program
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP - SIP	UNEP - Sustainable Infrastructure Partnership
UPGE	*Union Professionnelle du Génie Ecologique* / Professional Union of Ecological Engineering, France
WB	World Bank
WP	Work Package
WWF	World Wildlife Fund for nature

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1. INTRODUCTION

1.1. Objectives of the BISON project

Through topic MG-2-10-2020, the call 2018-2020 Mobility for Growth was the first one issued by the EC on the topic of transport that directly integrates biodiversity issues [cf. Section 1 of BISON project booklet]. As part of the last call under H2020, the BISON project is an opportunity to set the ground and upscale research on these topics in the next European research framework programme 2021-2027 (HORIZON EUROPE). Whilst the Green Deal aims at improving the transversal approach of topics and sectoral policies, the BISON project aims to address the mainstreaming of biodiversity with infrastructure development (which includes energy production and distribution), while addressing also pollution and/or climate change interactions with the overall biodiversity decline concern. Lastly, as a Coordination and Support Action (CSA), the BISON project aims to facilitate and enhance pan-European cooperation between:

(i) Member States (such as governments, national research centres, infrastructure operators and civil society) which are expected to be long-lasting and further strengthened beyond the timeline of the project; and,

(ii) All forms of infrastructure (including road, railways, waterways, airports, ports or energy transport networks) by creating synergies, identifying common needs for research and innovation, and sharing good practice to avoid and mitigate impacts on biodiversity.

By providing a forum for sharing solutions and lessons learnt, as well as identifying common issues, the BISON project aims to contribute to breaking the borders between the fields of biodiversity preservation and infrastructure planning and maintenance. It aims also make research and innovation more efficient through mutualisation of existing knowledge.

The BISON project aims to achieve the above through the following specific objectives:

● To identify future research and innovation needs for a better integration of biodiversity with infrastructure planning, construction, operation and decommissioning (the stages design and adapting have been added in the process developed in WP4). The project aims to develop a Strategic Research and Deployment Agenda (SRDA) which can be deployed at multiple scales, within the EU research framework programme, or by other regional, national or local programmes, in order to improve the knowledge-base on infrastructure and biodiversity.

● To make linear infrastructure more high performing and reliable while taking into account the specific needs of Western (e.g. need to adapt existing long-lived infrastructure to environmental changes, to support declining native species…) and Eastern (e.g. need to mitigate land-use change and habitat fragmentation due to the surge in infrastructure developments that are threatening the local very often endemic biodiversity) Europe.

● To support European Member States to fulfill their international commitments by engaging all stakeholders into biodiversity mainstreaming for infrastructure planning and development. The project

aims to provide recommendations to minimise the impacts of infrastructure on biodiversity through supporting existing and developing projects.

● To support European Member States to become political leaders through collaboration and support of European research institutions and infrastructure operators, and providing more sustainability at the international level through jointly addressing biodiversity and infrastructure challenges.

1.2. Objective of BISON WP4 and its specific approach

In the framework of the BISON project, the specific objective of BISON Work Package 4 (Towards a Research Agenda for Europe) was to elaborate the research side of the SRDA, namely the Strategic Research Agenda (SRA). A Strategic Research and Deployment Agenda aims to define the vision, overall goals, main technical and non-technical priorities, investment areas and a research and deployment roadmap for all types of European stakeholders[1]. BISON WP4 was about implementing a methodology to identify and classify research needs, aiming at producing a SRA for more biodiversity-friendly transport infrastructures and modes in Europe.

1.2.1. Starting from a blank page

The transport infrastructures considered in the Strategic Research Agenda are roads, railways, waterways, power lines, pipelines, airports and harbours (François et al., 2021 - D4.1). Regarding the issue of biodiversity-friendly transport infrastructure, no SRDA or similar strategic document had been drafted before the BISON initiative neither in Europe nor in the rest of the world. As a result, drafting the research side of the SRDA had to start from scratch. However some strategic research agendas from neighbouring fields were available and were consulted in order to draw inspiration in terms of form and content for WP4 and the Strategic Research Agenda. This was the case for airports (ACARE, 2017a,b), railways (ERRAC, 2019; Chéron et al., 2020), transport infrastructures in general (Bousmanne et al., 2019) and for biodiversity (Eggermont et al., 2021). Due to their scope and audience, the two latter documents (namely the STRIA – Transport Infrastructure and the SRIA Horizon Europe Partnership on Biodiversity) were the two main inspiring documents regarding the way to structure and dimension the SRA. As an example, the STRIA – Transport Infrastructure expresses 133 research actions distributed in 33 “topics”, themselves grouped into 9 “thematic areas”. The SRIA Horizon Europe Partnership on Biodiversity expresses 107 research actions distributed in 9 “sub-themes” grouped into 5 “themes”.

1.2.2. Involving all types of stakeholders

In order to allow the widest and most renewed reflection as possible, the methodology for elaborating the Strategic Research Agenda was not only to draw on the broad and varied knowledge and experience of BISON members and the scientific literature, but also to open the process to collect and analyse views from all concerned stakeholders (bottom-up approach).

[1] Definition from Ideal-IST, https://www.ideal-ist.eu/spotlight/strategic-research-innovation-and-deployment-agenda-srida

By the way, this methodology echoed an expectation formulated by the call topic MG-2-10-2020 for the provision of “a Strategic Research and Deployment Agenda (SRDA) endorsed by the national transport infrastructure authorities and the public innovation programme owners, representing the societal and environmental needs and requirements for infrastructure innovation”. The “agenda [was expected to] take input from relevant industry stakeholders, in close cooperation with the research community as well as agencies which will supply innovative solutions…”. Hence, involving all stakeholders in the process for the construction of the SRA was not only a way to ensure a broad vision of the situation regarding research needs (analysis of needs, proposals, weak signals). Regarding the research side of the SRDA, it was also a way of facilitating future endorsement of proposals thanks to research actions that had undergone a broad and transparent collective scientific validation process.

1.2.3. Three steps to elaborate the strategic research agenda

As a result, the methodology of BISON WP4 was composed of 3 steps, corresponding to the 3 successive tasks:

- Task 4.1, entitled “Stakeholders’ vision on societal and environmental needs and requirements for infrastructure innovation” (January to July 2021,) aiming to collect expectations and proposals from stakeholders;

- Task 4.2, entitled “Identification of innovation paths in view of Changing demand, Social changes, Climate, Biodiversity, Technology and Digitalisation” (August 2021 to January 2022) aiming to analyse and classify all identified issues;

- Task 4.3, entitled “Prioritization of research issues and initiatives for European agenda” (February 2022 to June 2023) aiming to prioritise research actions according to their environmental importance and the gap with the current state of knowledge This task also includes a reflection on the research environment as such on the subject addressed by BISON and on the issues of its future funding.

In order to build a relevant and applicable SRA, it’s most important to be aware of the points of view of all types of stakeholders regarding the situation, their expectations and their possible proposals, as well as to consider their points of view on the prioritization of future research initiatives. That's why, in its first step the methodology was designed to take input from stakeholders on their expectations and proposals, and in the third step, to get their feed-back on research initiatives and their schedule (external review of the SRA before validation). Figure 1 presents the general articulation of the method steps. Stakeholders were notably environmental agencies, research institutions, transport management and infrastructure construction enterprises, non-governmental organisations, transport authorities.... Deliverable 4.1 (D 4.1, July 2021), resulted from the first step of the method and served as major document for the process. The broad detailed overview of research needs that resulted from the second step (Milestone MS 4.1, January 2022) was the basis for the construction of the SRA (third step): consultation of stakeholders on identified research questions, confrontation with outcomes of other work packages.

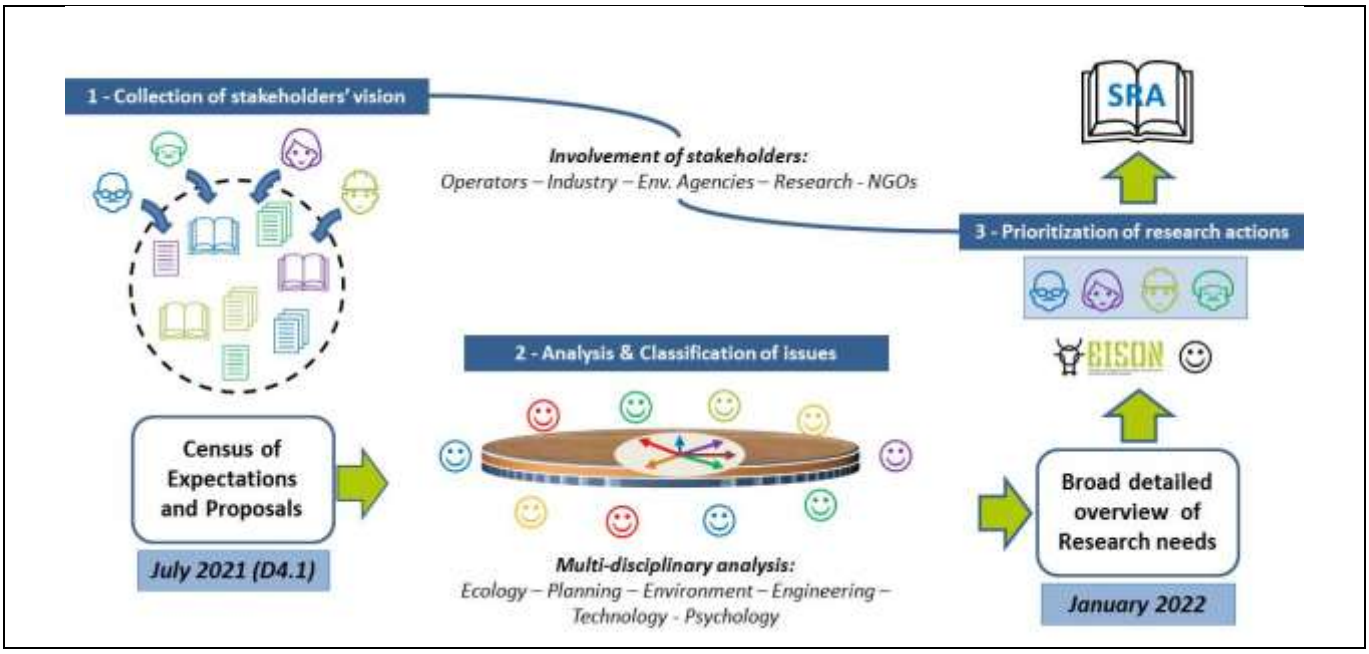


Figure 1. The 3 step-approach to elaborate the SRA

1.2.4. Connexion with other WPs

As indicated above (§ 1.2.2), in order to allow the widest and most renewed reflection as possible on research for more biodiversity-friendly transport infrastructure, no selection was applied regarding scientific criteria, neither at the stage of input collection (Deliverable D 4.1) nor at the stage of their interpretation under various angles (Milestone MS 4.1). This resulted in the need to address a high amount of expectations and proposals (Task 4.1) and a very high amount of raised questions and potential issues for research (Task 4.2). The way this was managed is detailed in Section 3 of the document.

The first reason to proceed this way was to give more time as possible to the analysis of the research dimension of a given issue before to decide of its fate regarding inclusion or not in the strategic research agenda. Typical questions were: Had the question been properly formulated and/or analysed regarding its research potential? Did it contain hidden, unresolved aspects? Did it involve upstream, downstream or collateral issues?

The second reason to proceed this way was to keep track of issues identified as relevant for the general problematics of biodiversity-friendly transport infrastructures, regardless they were identified as research actions or not. Were eligible in the Strategic research agenda, activities of research and development (R&D), not those related to deployment (EARTO, 2014; OECD, 2015; Palluault & Omer, 2022). Hence, during the WP4 approach development it was possible to check consistency of some inputs with certain initiatives and findings of other work packages of BISON. The opportunity to assess such convergence was given thanks to workshops and some deliverables progressively elaborated in WP2 (Mertens, 2023), WP3 (Guinard, 2022; Seiler et al., 2022; Moulherat et al., 2022), WP4 (François et al., 2021) and WP 5 (Loukea & Chevalier, 2022; Georgiadis et al., 2022), and thanks to the exchanges allowed by the consultation of BISON members, notably WP and task leaders (see Section 3). In the end, the traceability of all actions needed for more biodiversity-friendly transport infrastructure - both research actions included in the Strategic Research Agenda and non-research actions no included in the SRA - has been preserved, from the initial entry (from Task 4.1 to Task 4.3).

2. THE METHODOLOGY, STEP BY STEP

Aiming to answer to the multidisciplinary characteristics of the problematics of biodiversity-friendly transport infrastructures, the team constituted for elaborating the strategic research agenda (SRA) was made from a great variety of competences, at both operational and research levels. In order allow the widest possible reflection for the construction of the SRA, the approach was not only to draw on the knowledge and experience of the work-package (WP4) members, of BISON members and the literature. The approach was also to open the process to all concerned stakeholders, in order to collect their views of needs (bottom-up approach), then to carry out a need analysis to possibly identify new research topics. Stakeholder participation also concerns the results of the process. Their consultation on proposed research actions allows to test their suitability for end users and to optimise their adoption.

The present section presents, step by step, the process that has been developed following this approach aiming to bring out the research actions that constitute the strategic research agenda for biodiversity-friendly transport infrastructures in Europe. This presentation goes with the provision of some intermediate results that are significant milestones of the process.

2.1. Step 1 - Collection of stakeholders' vision

In the aim of maximising the compilation of information, two collection methods were used. One was the direct consultation of stakeholders (Subtask 4.1.1). The other one was the review of documents published by the various stakeholders' organisations, from national to international levels (Subtask 4.1.2).

2.1.1. On-line consultation of stakeholders

Two questions were implemented in the online questionnaire[2] organised for the whole BISON project under the coordination of WP2. They were grouped under Question 1.5 – Expectations and proposals of for more biodiversity-friendly transports, as part of section "Strategic and planning aspects" of the questionnaire. Contributors to the question were asked to specify when a proposal of solution was related to a given expectation. Figure 2 presents the two parts of Question 1.5 online. Participants in the consultation were asked to specify whether they were contributing on behalf of their organisation, as individuals, or both.

Lists of addressees among international, European, national and sub-national institutions representative and relevant for the different kinds of stakeholders were drawn up for the dissemination of the questionnaire. All BISON members were asked to contribute to these lists by providing contacts (representatives of institutions, experts) in their country and professional networks.

The BISON online questionnaire was made available from 26 April 2021. BISON members were charged to disseminate the information among their contacts and were invited to contribute to the consultation. Regarding the preparation of Deliverable 4.1, hence answers to its Question 1.5, contributions were considered until 23 June 2021 (i.e. 6 weeks opened to consultation). Monitoring of

[2] https://bison-transport.eu/bison-questionnaire/

answer collection to Question 1.5 and classification of expectations and proposals provided by participants were achieved by P. Mederly (UKF).

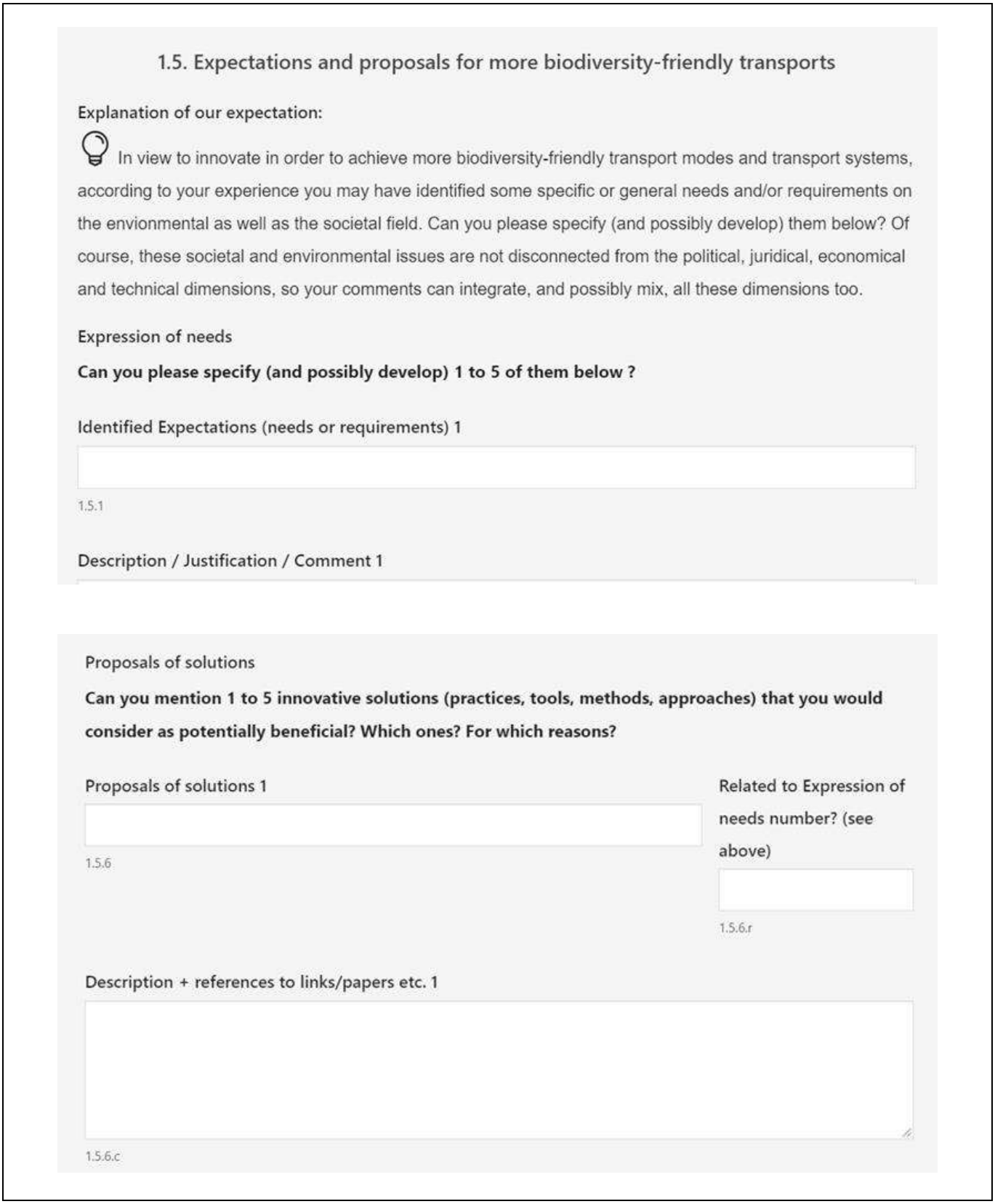


Figure 2. Step 1 - Question 1.5 of the BISON online questionnaire

2.1.2. Document survey among stakeholder organisations

Subtask 4.1.2 echoed to the online consultation with the same questions (#Issue 1: expectations; Issue 2: Proposals). But in that case they were investigated across the documents published by the diverse stakeholders' organisations acting at national, European and international levels. It complemented and contextualised the inputs of online voluntary contributions. The most relevant documents to find such information were those of strategic or policy nature (e.g. multi-annual plans, strategic agendas…), position or visionary papers, analyses of gaps, innovative methodologies… Investigated documents were those produced in the last decade.

Document information:

Title:

Language:

Short description of document (up to 100 words on aim and legal binding):

Originator of document:

Full bibliographic reference in APA style:

Download link to online version (if available):

 # Issue 1: Expression of expectations (needs, requirements) for improving infrastructures in view of more biodiversity-friendly transport modes and transport systems. These expectations may regard the environmental and societal dimensions but also political, juridical, economical and technical dimensions.

Identified Expectations (needs and requirements):

Text	References (page or chapter in document)	Thematic (A/B/C/D)	roads	railways	waterways	power lines	pipelines	airports	harbours

 # Issue 2: Expression of possible innovation solutions or paths for more biodiversity-friendly transport modes and transport systems. They may regard practices, tools, methods, approach of the problems. Proposals can result from experience feedback or can be purely theoretical at that stage, born from observation and reflection.

Proposed solutions:

Text	References (page or chapter in document)	Thematic (A/B/C/D)	roads	railways	waterways	power lines	pipelines	airports	harbours

Explanation:

Full bibliographic reference: use APA style; free online tool is available from https://www.scribbr.com/apa-citation-generator/

Thematic: A= Policy and strategies; B=Planning and environmental impact assessment; C= Implementation and management; D= Education, awareness, consultation and communication. If other than A/B/C/D, specify.

Modes of transport: mark with "X" all relevant modes

Figure 3. Step 1 - Document information form

To begin, WP4 members were asked to analyse documents from their own institution, country and also from the international/European organisations they could be member. A document information form, intended to report on the expression of expectations and proposals in those documents was developed and made available to WP4 members. The structure of the document information form is shown in Figure 3. Readers of documents were asked to rank the identified expectations and proposals according to four thematics: A - Policy and strategies; B - Planning and environmental impact assessment; C - Implementation and management; D - Education, awareness, consultation and communication, otherwise, to specify. Documents obtained from national levels were from France (EGIS group, ATEC-ITS France, IDRRIM, IFSTTAR, Routes de France, TDIE; Vinci Autoroutes; OFB; SNCF; IRSTEA; CNRS; UAF&FA; IAU; MTES; CILB; Aéro-biodiversité; CESE), Slovakia (MDV; MIRRI; MŽP; City of Žilina; RPS); Ireland (TII), Austria (AWC); Switzerland (U. Geneva); UK (HS2).

In a second time, the search and the analysis of documents from stakeholder institutions acting at European and international level was carried out. The search for relevant documents from these organisations was achieved by the WP and Task leaders. Then, the analysis of documents was shared between several WP4 partners (Amphi-FFPE, CDV, Egis, OFB, STUBA, TII, UIC, UGE, UKF and UPGE). Table 1 presents all the institutions that were investigated at international and European levels.

Through WP2 (C. Navarro, Y. Autret), some volunteer members of the Advisory Group (so-called "involved" members) towards this aspect of the BISON project were asked to provide relevant documents from their institution. This happened notably (see Table 1) towards the representatives of CER (Community of European Railway and infrastructure companies), EIM (European rail Infrastructure Managers), UNEP-SIP (United Nations Environment Programme – Sustainable Infrastructure Partnership), WWF-US (World Wildlife Fund - United States) and ACLIE-EWT (African Conference for Linear Infrastructure and Ecology - Endangered Wildlife Trust).

The same document information form was used (Figure 3). The monitoring of document information form collection and the classification of expectations and proposals identified in the documents were achieved by I. Dostál (CDV).

Table 1. Major international and European institutions identified for the document survey

Institutions relevant in…		**… at international level**	**… at European level**
Transport sectors	Roads	PIARC ; GIB Foundation	CEDR
	Railways	UIC	ERA ; CER ; ERRAC
	Waterways	PIANC	EBA
	Power lines	-	ENTSO-E
	Airports	**-**	ACARE ; ACI Europe
	Harbours	IHMA ; IMO ; UN WPSP ; AIVP	ESPO ; EFIP ; SEA Europe
	Various	OECD ; WB ; ISO/TC331	EC ; EIB ; EBRD ; T20
Environment protection		IUCN ; WWF ; IPBES ; UNEP(-SIP) ; CBD	EEA ; WWF Europe ; UNEP(Carpathian Convention) ; HARMON
Research		ICOET ; TRB ; ACLIE-EWT ; ANET	IENE ; FEHRL

2.1.3. Intermediate results of Step 1

The detailed results of the on-line consultation and the document survey are provided in Deliverable 4.1 (François et al., 2021). The present section is just a reminder of the main characteristics of the information sources gathered through the first step of the WP4 methodology.

Deliverable 4.1 being scheduled 31 July 2021, data from the on-line consultation were integrated until 23 June 2021 (59 days of survey, 47 contributors to questions Q1.5 and/or Q1.6). However, as the BISON on-line questionnaire was still running until 1st September 2021, the collection of possible late contributions to WP4 questioning was continued. In the end, 61 contributors to questions Q1.5 and/or Q1.6 were counted, from 21 countries, plus 2 international organisations (Figure 4). Their distribution was fairly balanced between the different types of stakeholders concerned by the BISON project, with universities and research institutes being the only ones more represented (Figure 5), similar to the situation reported in Deliverable 4.1. Most of the contributors declared expertise in the fields of roads and railways (≈80%), around half in the fields of airports and waterways, a third in the fields oh harbours and powerlines, and just a fifth in the field of pipelines (Figure 6). Such distribution was similar to the one reported in Deliverable 4.1.

Details of the 80 documents analysed in the survey are provided in the Reference section. Figure 7 shows the diversity and representativeness of these publications. The most important part was from NGOs and associations (including international professional associations). Almost a quarter of them originates from public agencies, then a tenth from universities and research institutes. The other types of organisations (transport administrations, transport infrastructure companies, environmental administrations, environmental consultancy and general administrations) share the remaining 23%.

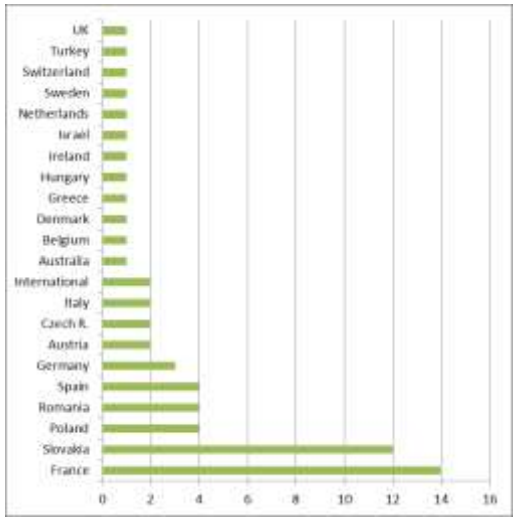


Figure 4. Step 1 – Online contributors: Countries

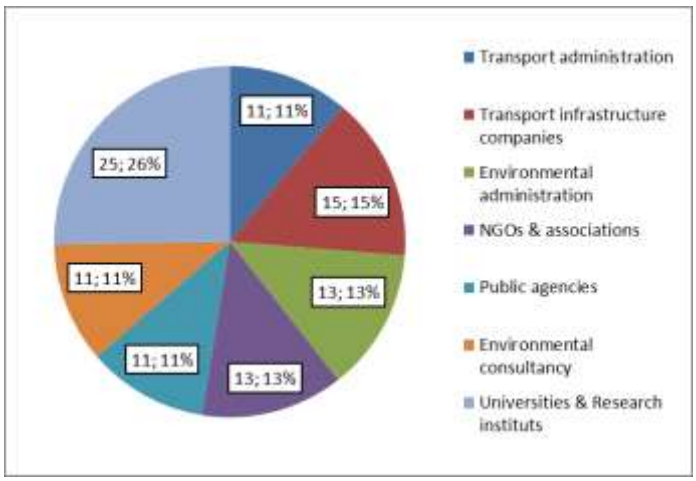


Figure 5. Step 1 – Online contributors: Type of organisation

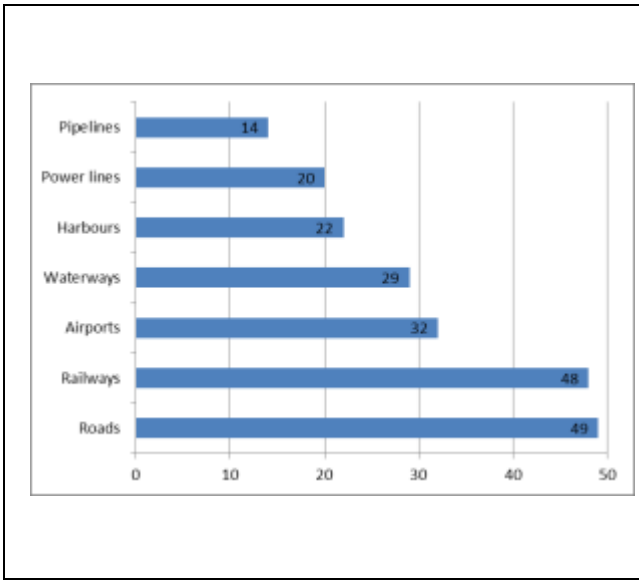


Figure 6. Step 1 - Online contributors: Transport infrastructures

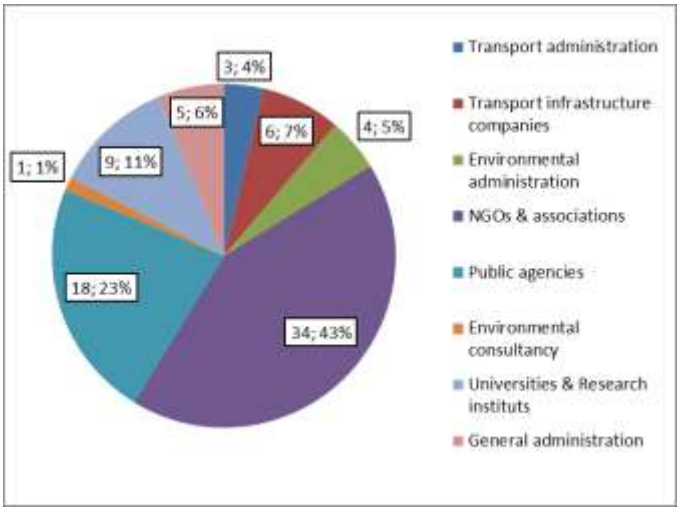


Figure 7. Step 1 - Document survey: Type of organisation

A total of 135 expectations and 83 proposals have been formulated through the on-line consultation and a total of 190 expectations and 231 proposals have been identified by means of the document survey. Their distribution among the 4 thematics used for classification is presented in Figure 8 to 11. Contributors to the online consultation showed consistency regarding the share given to the 4 thematics between expectations and proposals (Figures 8 and 9). Institutional documents are not that consistent between expectations and proposals. The thematic Policy & strategy is important in expectations and poor in proposals, and it's the opposite regarding the thematic Implementation & management (Figures 10 and 11).

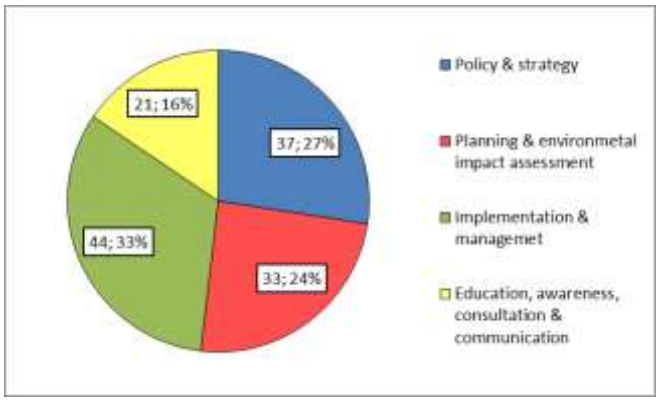


Figure 8. Step 1 - Online consultation: Expectations

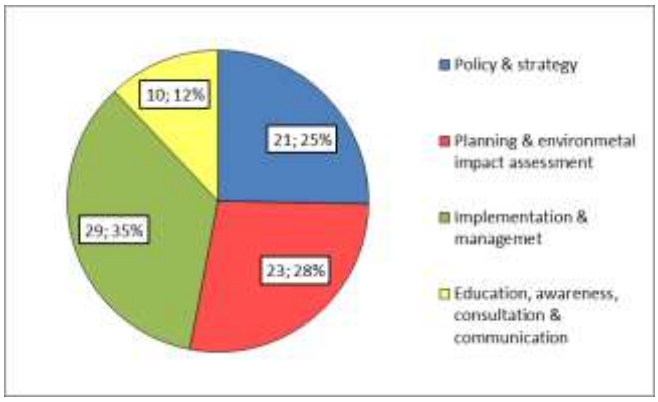


Figure 9. Step 1 - Online consultation: Proposals

The 639 expectations and proposals identified through the online consultation and the document survey are extensively presented into Appendix A (Census of expectations) and Appendix B (Census of proposals) of Deliverable 4.1. They have been the inputs to the next step of the methodology.

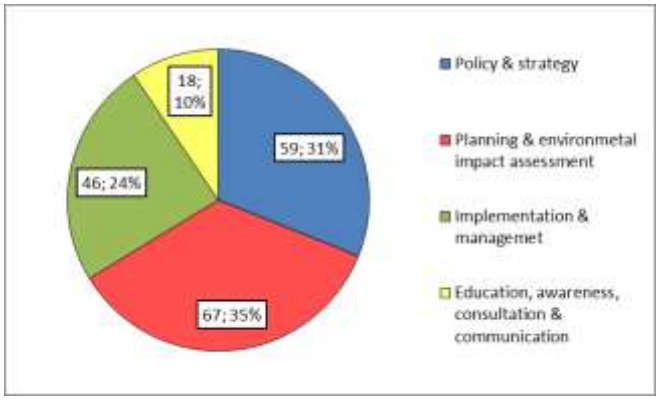


Figure 10. Step 1 - Document survey: Expectations

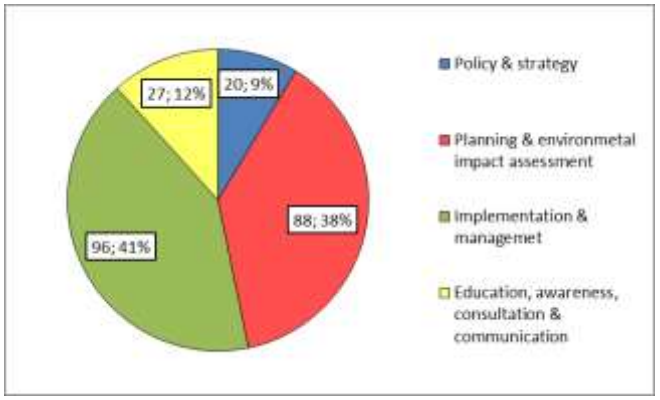


Figure 11. Step 1 - Document survey: Proposals

2.2. Step 2 – Analysis and classification of issues

2.2.1. Process to identify potential issues for research (PIR)

The aim of the second step of the methodology was to achieve a broad and detailed overview of research needs identified through expectations and proposals expressed by all concerned stakeholders. The tool intended to reveal these research needs in any area of relevance for the problematic of biodiversity-friendly transport infrastructures, was the capacity for multidisciplinary analysis developed thanks to the diversity of skills of WP4 members. Indeed, skills gathered by contributors to Task 4.2 were in the fields of ecology, ecological engineering, landscape ecology, spatial planning, landscape planning, land use, environmental sciences and technologies, environmental monitoring, transport geography, sustainable development, road and railway engineering, transport systems, social psychology, political sciences, life cycle analysis.

At the beginning of the project [cf. Section 1 of BISON project booklet], face-to-face meetings to gather and exchange the views of all the contributors and to brainstorm together on the most problematic issues was the formula envisaged to conduct Task 4.2. The covid19 pandemic made this impossible. A method of remote collaborative work had to be organised, abandoning the idea of brainstorming sessions, which were too difficult to conduct remotely.

As a result, the process was as follows. To begin, the full list of 639 inputs (expectations and proposals) was subdivided into a series of 10 batches. Successive batches counting around 63 inputs from Deliverable 4.1 were made available to voluntary contributors at a weekly rhythm. This way, all contributors had to work on the same batch (n° 1 to 10) at the same time. On the given batch, contributors were asked to express the raised questions (RQ) from their point of view from the series of 63 inputs. They also add to tick what kind of transport infrastructure was concerned by the RQ as well as what stage of the transport infrastructure life cycle. Files from contributors (inputs with their

associated RQ) were then centralised and compiled to build weekly batches of the diverse raised questions (I. Dostál). The traceability between inputs (Deliverable 4.1) and their raised questions was achieved by means of an alphanumeric code to each RQ. A total of 12 contributors took part to this analysis, with an average of 8,3 contributors per week over the 10-week period. These were members of CDV (I. Dostál, J. Jedlicka), UGE (L. Bosone, M. Dauvergne, D. François, N. Hautière), UKF (P. Mederly), UPGE (C. de Roincé), AMPHI (A. Aliaga), OFB (N. Hette-Tronquart), EGIS (A. Rauline-Mougeot) and UIC (M. Pignel).

Weekly batches of RQ were then circulated (I. Dostál) to 5 partners, "sub-task leaders" that were responsible for taking into account the RQs and possibly formulate from them the so-called potential issues for research (PIR). Each one was responsible to regard specifically issues related to a particular stage of the life cycle: planning, design, operating, adapting, decommissioning. A two-round process was implemented. RQs of the given weekly batch were first regarded for the Operating stage (D. François) with formulation of PIRs (reformulation of RQs to highlight the research question). Second they were regarded for the Decommissioning stage (P. Mederly) with assessment of the previous proposals of PIRs (i.e those formulated at Operating stage) and addition of complementary ones, third for the Design stage (A. Aliaga) with the same actions (specific RQs + new PIRs), fourth for the Planning stage (C. de Roincé), and fifth for the Adapting stage (I. Dostál). The second round made possible for each one to assess all additions of PIR, for all life stages. Hence, the output of the process was a single list of PIRs, with for each PIR the concerned transport infrastructure type and concerned life stage being specified. Figure 12 summaries the overall process developed in Step 2 and Figure 13 illustrates the specific stage of PIR formulation (round 1, red) and cross-validation (round 2, green).

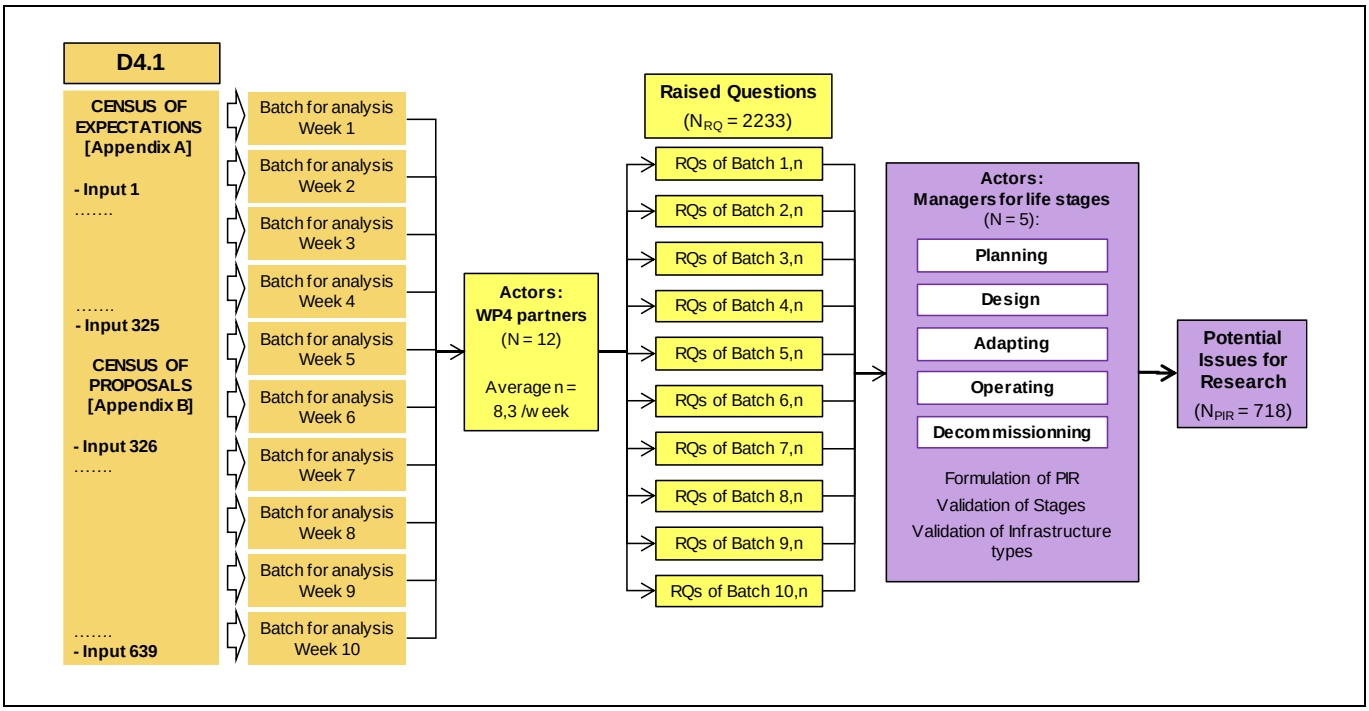


Figure 12. Step 2 - Processing of stakeholders' inputs to identify potential issues for research

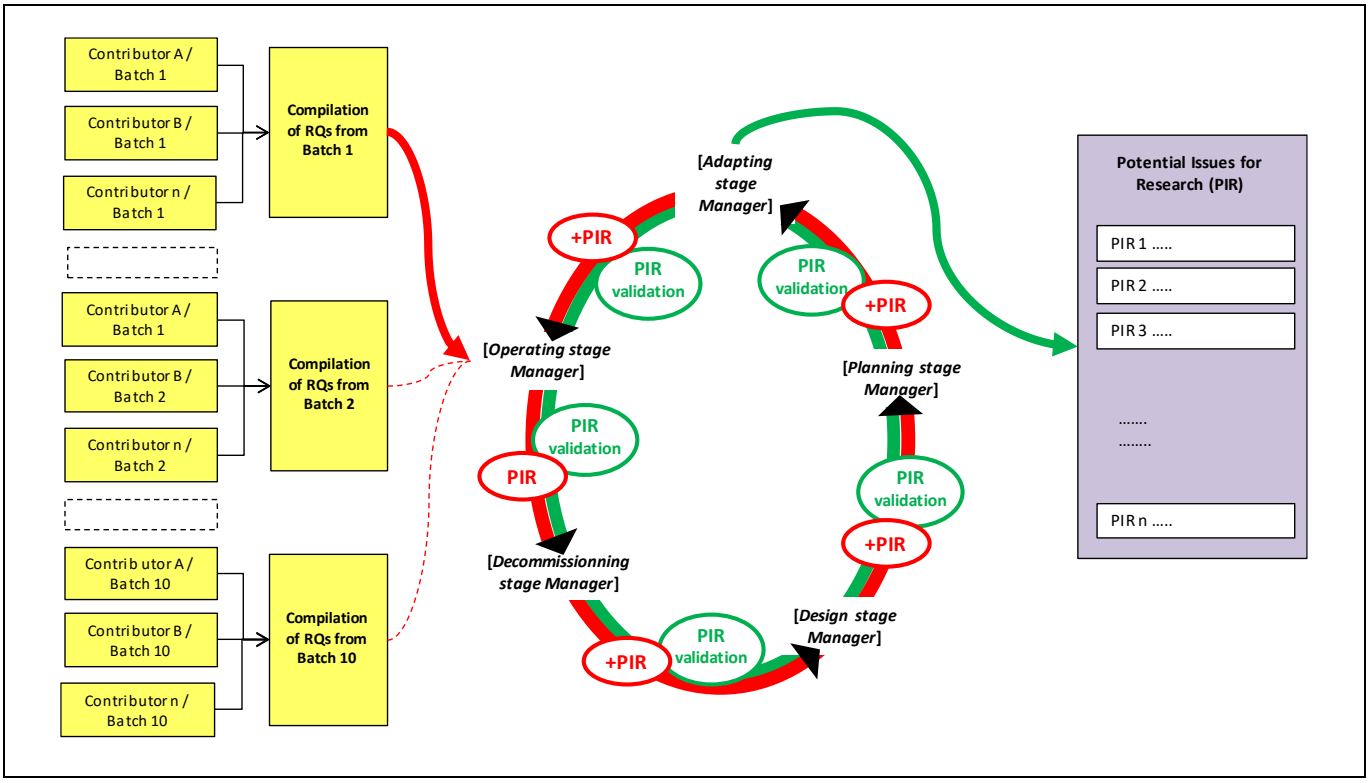


Figure 13. Step 2 – Detail of the process to formulate and validate PIRs

2.2.2. Intermediate results of Step 2

The first part of the process (12 contributors) led to the formulation of a total of 2233 raised questions (RQ). Hence, in average, an input gave rise to 3.5 questions. From these, the second part of the process, carried out by the 5 stage managers, led to the identification of 718 potential issues for research (PIR). The final number of PIR was high as a result of the very high amount of raw material (RQ), itself inherited from the high number and diversity of contributors in the first part.

In this second part of the process, the objective was to identify whether an original input (from Deliverable 4.1) was likely to highlight a potential issue for research (PIR). The latter could have the form of a general issue, a specific question or the need for tools (for research or from research). At this stage of the overall process, there was no objective (no need) to perform any filtering intended to merge similar PIRs. The latter action was planned for the next step.

The upstream traceability between PIR, RQs and the original inputs was continued (alphanumerical code) in view of the next step of the process, i.e. the merging and/or reformulation of issues to draft research actions (RA) for the strategic agenda.

The general result showed that many PIR were related to several life stages and several types of transport infrastructures, illustrating the well-known cross-cutting nature of many biodiversity issues among transport infrastructure types.This aspect will be further developed when presenting the final results (Research actions – RA) of the process. The cross-validated PIR were compiled to constitute the broad detailed overview of research needs, i.e. Milestone 4.1 (January 2022).

2.3. Step 3 – Prioritization of research actions

2.3.1. Process to bring out research actions (RA) from PIRs

As a result of no filtering action in the previous step, the number of PIR was high (n = 718) and achieving the search of similar research questions among them was difficult. Moreover, the wording of most PIRs was long which complicated comparison between them. Text mining techniques have been used to help overcome this difficulty.

Several sequences of text-mining were applied to the list of PIRs, using Sentence Transformers (Reimers & Gurevych, 2019), UMAP (Mc Innes et al., 2018) and HDBSCAN (Campello et al., 2015) frameworks, in the aim to suggest smaller groups within which it was easier to see similarities between PIRs. The vocabulary of PIRs was harmonized as far as possible to facilitate the text-mining process. Four successive sequences of text-mining were necessary to rank all the PIRs into 52 clusters (and sub-clusters) counting 5 to 45 PIRs. The aim of this was to identify similar questions in order to merge them in a single research action. But the aim was also to identify links between questions, such as causal relationships (upstream/downstream questions) and such as tree-structure relationships (questions and sub-questions). Thanks to this process, it was possible to draft a first list of 192 RAs. The traceability of RAs with the PIRs, RQs and original inputs was preserved.

In order to obtain support and lightning insights in the analysis of PIRs with social and socio-psychological aspects, a specific brainstorming session was organised (22 February 2022) where several potential research issues were submitted to a panel of experts. The main axis of reflexion in view of formulating research needs was the position of the social actors: field staff, intermediate staff, head, users, general public. The **"brainstorming session on social dimensions**" was organised with the support of WP2 (C. Navarro) and gathered 9 participants: C. Navarro (FRB, BISON WP2), A. Mertens (Agristudio BISON WP2), O. Pichard (Cerema, BISON WP3), L. Bosone and D. François (UGE, WP4), N. Drouin (Kheops, Canada), J. Jurik (GIB, Switzerland), A. Laur (CLLC, USA), E. Lozos (Duke University, USA).

The original list of 192 RAs was analysed by Task 4.3 managers (D. François, I. Dostál, P. Mederly). In order to provide clear, simple and non-ambiguous understanding, the wording of research actions was standardized following the format: WHAT (Action) FOR WHAT (Objective). The list was submitted to a specific step of text-mining in order to light possible mergers and cancellations among RAs. The subsequent analysis led to a list of 156 RAs. This was offered to the comment by contributors to the previous step in WP4 in the aim to collect comments on the relevance of the RAs, on possible additional mergers and on the quality of wording (May 2022). This first stage of improvement resulted in a revised list of 146 RAs intended to be submitted to other BISON members with the same objectives.

2.3.2. Consultation within BISON

This stage was opened to consultation to all BISON members for testing RAs. Work-package leaders and task leaders were particularly targeted as potential holders of the widest and most up-to-date information on needs and state of knowledge. On the occasion of the BISON general assembly in Paris

in June 2022, a workshop “BISON Strategic Research Agenda Version 0” was organised to explain the whole process and initiate this second stage of consultation (9 June 2022). The workshop gathered 31 participants from 11 countries. In the end of summer 2022, comments had been received from 11 persons from Agristudio (Italy), BASt (Germany), BfN Germany), Generalitat de Catalunya (Spain), Minuartia (Spain), OFB (France), University of Kassel (Germany), University of Kiel (Germany) and University of Limoges (France).

Taking all these comments into account, an improved list of proposals (consolidation of some RAs, cancellation of some RAs, merging of some RAs, improving wording) was drawn up, resulting in an improved list of 114 RAs. This list was intended to open consultation out of the circle of BISON members (see Section 3.3.3).

In addition to individual consultation, some deliverables of BISON were considered. Indeed, the topics of several deliverables produced in other work-packages of BISON CSA presented links with some fields tackled for the construction of the SRA. This was the case of deliverables D3.2, D3.4, D3.5, D5.1 and D5.2. These documents have been reviewed, read or even cross-read by WP4 members. This made it possible to check the consistency of the RAs identified through the WP4 approach with the results and needs expressed in these documents. In case of doubt about possible deviations, discussions were held with the authors of the given deliverables. Thus, along the process specific discussions took place with some authors to check certain issues relative to law (D.5.1), social psychology (D3.4) and information technology (D.3.5) in view to modify, delete or add RAs accordingly.

2.3.3. Consultation with stakeholders outside BISON

With the support of WP2 (C. Navarro) an online workshop was organised with members of the **IENE Scientific and Expert Committee** in order to present and exchange on the Strategic research agenda (22 June 2022). They were 10 members of the SEC to participate. They were asked to express their ranking and comments relative to the priority level of RAs of the list (top, medium or low priority). Contributions were received from 6 members and their comments were taken into account in the revision of the list for the following consultations.

The opportunity for a live interaction with the broad community of stakeholders of transportation ecology in Europe was given by the workshop “Relevance and prioritization of research actions for biodiversity-friendly transport infrastructures in Europe” that was organized in Cluj-Napoca, on the occasion of the **IENE 2022 conference** in September 2022 (in Berchi et al. 2022, p. 148). This workshop was organised and facilitated by partners of WP4 (N. Hette-Tronquart and O. Deyrieux - OFB; A Aliaga - Amphi; I. Dostál and J. Jedlicka - CDV; P. Mederly - UKF; D. François - UGE). They were 28 participants from 13 countries to take part in this workshop (22 September 2022). Participants were asked to express their opinion on the relevance, importance and understanding on the proposed RAs.

The opportunity for a live interaction with representatives of the community of stakeholders of transport systems in Europe was provided by the BISON invited session that was organised in Lisbon on the occasion of the **TRA 2022 conference** in November 2022. As part of this session (16 November 2022), a consultation “The BISON research agenda for mainstreaming biodiversity with transport infrastructures in Europe” was organised (D. François, I. Dostál) to question participants about a

selection of the 20 RAs considered as the most valuable according to the process developed until that stage. They were 14 participants from 7 countries (France, Germany, Ireland, Italy, Slovenia, Sweden and UK) to answer to this consultation. They were asked to express their opinion on the relevance (strong, weak or null) of the proposed RAs and on the research effort to address the given RA (high, medium or low), as a proxy knowledge gap and necessary investment.

The analysis carried out from these two consultations led to additional improvements in the list of RAs: wording, merging, cancellation and also the addition of a new RA. The resulting list of 110 RAs was intended to be submitted to the last stage of external consultation by members of the **Advisory group of BISON**. In addition to their level of expertise, in order to get a completely fresh look at the proposals, only people who up to this point had not been involved at all in the process were invited to contribute (February 2023). Five members agreed to carry out this assessment: M. Heiming (EIM, Belgium), E. Losos (Duke University, USA), R. Palmer (UN Environment Program), C. Cremezi (SNCF, France) and C. Steenbeck (Vejdirektorat, Denmark). They were asked to express their opinion on the relevance of each RA (strong, weak or null), on the research effort needed to achieve the RA (high, medium or low) and on the urgency to address the RA (high, medium or low).

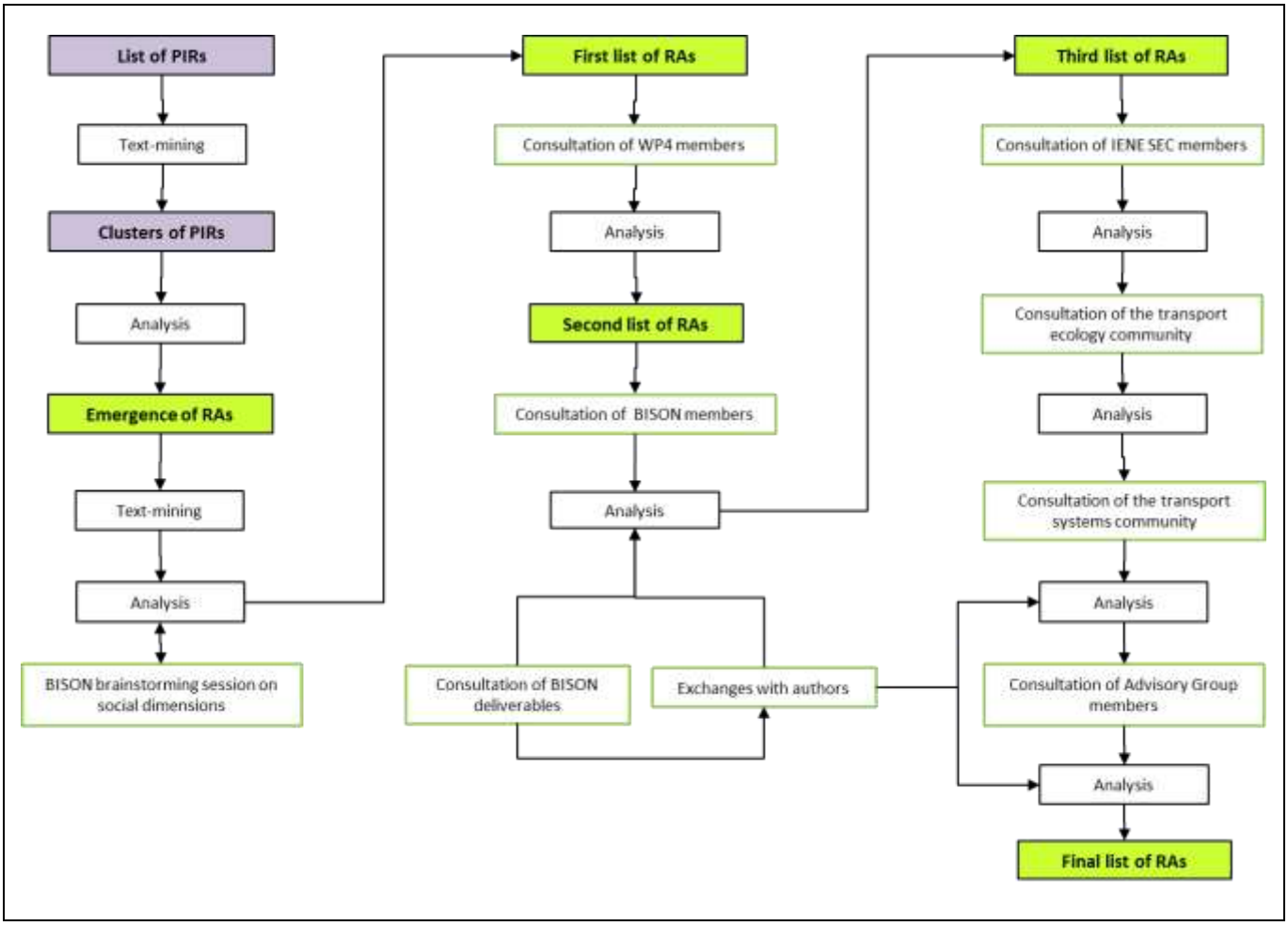


Figure 14. Step 3 – General process developed to bring out research actions from PIRs

The WP4 members involved in the analysis of comments and votes collected through the consultations of BISON members (after WP4 members), of persons of the transport ecology community, of persons of the transport systems community and of the Advisory group members were O. Deyrieux and N. Hette-Tronquart (OFB) and M. Dauvergne and D. François (UGE). This involved assessing the level of relevance of RAs in order to select them for the research agenda, improving the wording of RAs in order suppress misunderstanding riks, and also assessing the level of maturity of RAs with respect to the general research and technical development process (see reference systems in § 2.3.4 and § 2.3.5). Figure 14 summaries the general process developed in Step 3 aiming to bring out the list of research actions for the Strategic research agenda.

2.3.4. Two systems available to express the maturity level of RAs

Providing a strategic research agenda implies estimating the time horizon within which it is desirable (according to society or research expectations) and possible (according to research capacity) to carry out the proposed research actions. This time horizon depends on factors such as the gap between current knowledge and the knowledge needed, on the difficulty of bridging the gap (i.e. research effort needed for), on the importance and urgency of solving the problem for concerned stakeholders or society for operational purposes, or for next steps in the research/innovation process.

The expertise and opinion of WP4 and BISON members as well as stakeholders outside BISON have been requested to provide inputs to estimate these factors for the different RAs, in view to formulate the most appropriate time horizon for each one. Indeed, there is no methodological tool available today to characterise with a single approach the maturity level of such multidisciplinary issues as those of the biodiversity-friendly transport infrastructures. Hence, an approach according to experts was unavoidable to draft the strategic agenda for research for biodiversity-friendly transport infrastructures in Europe.

However, two tools are available today to assess the maturity level of research, development and innovations actions for two dimensions of importance for the research actions related to biodiversity-friendly transport infrastructures in Europe. One is the Technology Readiness Level (TRL) developed in the 1970-80's in the USA (by the NASA) and commonly used today at EU level for decision making in RDI investments (EARTO, 2014). The second one is the Societal Readiness Level (SRL) originally proposed in 2019 in Denmark (IFD, 2019) and further developed in France (CNRS, MSHS of the University of Poitiers, Ellyx) and still at the stage of experimental prototype today (Palluault & Omer, 2022).

For several reasons both tools are worth being considered to build the strategic research agenda.

The first reason is that, from near or far, most research actions for biodiversity-friendly transport infrastructures are connected to one or two of the dimensions tackled by TRL and SRL (engineering, behaviour…).

The second reason is that, despite its technology-only scope, the TRL system is commonly used worldwide and has been used for decades as the main reference framework for innovation funding and support schemes (Palluault & Omer, 2022). It is therefore a classification system to which the actors of the field are accustomed to handle new proposals. That's why, as far as possible/relevant RAs have

been positioned with respect to this system to be understood by actors. Table 2 specifies the 9 levels of the TRL scale, which is used in the EU Horizon 2020 work programme notably.

The third reason is that the SRL system is designed to address a more comprehensive and more global vision of innovation and a broader panel of actors than the TRL system (Palluault & Omer, 2022). It is able to treat the capacity of society to integrate solutions - should they be technical or not – intended to overcome problems raised in the last decades, such as the protection of biodiversity, the management of natural resources, equity, governance… Hence, it is a system which use is called to grow in importance in the future and to become a reference for the problematics of biodiversity-friendly transport infrastructures. Table 3 specifies de 9 levels of the SRL scale, which notably shows the absence of laboratory experiments in sociology, compared to the TRL reference system, and which is closer to the situation for research in ecology.

The fourth reason to consider TRL and SRL scales is that both systems allow to characterize the situation of issues/actions that are already enough mature to be downstream from the field of research and development. Such issues/actions already belong to the field of deployment and as such are out of the scope of the strategic research agenda. The scales of TRL and SRL have been used to assess this point. RAs of the strategic research agenda belong to the fields of research and development, their TRLs and SRLs, do not exceed the values of 6 and 7 in the respective scales (red and yellow phases in Tables 2 and 3).

Table 2. TRL scale (from EARTO, 2014 and OECD 2015)

TRL Scale	Description	Sub-phase	Phase
TRL 1	Basic principles observed	Invention	Research
TRL 2	Technology concept formulated		
TRL 3	Experimental proof of concept	Concept validation	
TRL 4	Technology validated in a lab		**Development**
TRL 5	Technology validated in relevant environment	Prototyping	
TRL 6	Technology demonstrated in relevant environment	Pilot production and demonstration	
TRL 7	System prototype demonstration in an operational environment		**Deployment**
TRL 8	System completed and qualified	Full market introduction	
TRL 9	Actual system proven in operational environment	Market expansion	

Table 3. SRL scale (from Palluault & Omer, 2022 and IFD, 2019)

SRL Scale	Description	Definition	Phase
SRL 1	Basic research	Original approach to a societal issue. Re-problematisation work. The needs are described	**Prematuration - Research**
SRL 2	Concept characterisation	Characterisation of a concept in relation to the problematic societal issue.	
SRL 3	Concept validation	Societal validation of the concpet in relation to the socio-economic world (1st level of interest shown by the actors)	
SRL 4	Translation of the concept into a social innovation project	Identification and characterisation of the areas of application of the concept in society (2nd level of stakeholder interest)	
SRL 5	Pilot modelling	Identification and characterisation of the areas of application of the concept in society (2nd level of stakeholder interest)	**Maturation - Pilot**
SRL 6	Implementation of the pilot	Adaptation of the real conditions to enable the implementation of the pilot (change of settings and practices in the pilot environment)	
SRL 7	Operational functioning of the pilot	Deployment of the pilot in the real environment and follow-up. Operational demonstration of the pilot	
SRL 8	Conditions for spinning off and scaling up	Evaluation of dissemination conditions. Objectivation of impact	**Post-maturation - Deployment**
SRL 9	Integration into the wider society	Qualified and tested solution, available and standardised	

2.3.5. The three types of R&D activities

For more than half a century (i.e. since 1963), the Frascati Manual has provided the definition of research and experimental development (R&D) that has been used to gather data on financial and human resources allocated to R&D (OECD, 2015). According to the Frascati Manual, the term R&D covers three types of activity: basic research, applied research and experimental development.

- **Basic research**

Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view (OECD, 2015). Basic research analyses properties, structures and relationships with a view to formulating and testing hypotheses, theories or laws. The reference to no “particular application in view” in the definition of basic research is crucial, as the performer may not know about potential applications when doing the research. The Frascati Manual distinguishes Pure basic research from Oriented basic research:

- **Pure basic research** is carried out for the advancement of knowledge, without seeking economic or social benefits or making an active effort to apply the results to practical problems or to transfer the results to sectors responsible for their application.

- **Oriented basic research** is carried out with the expectation that it will produce a broad base of knowledge likely to form the basis of the solution to recognised or expected current or future problems or possibilities.

● **Applied research**

Applied research is original investigation undertaken in order to acquire new knowledge but it is, however directed primarily towards a specific, practical aim or objective (OECD, 2015). Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives. It involves considering the available knowledge and its extension in order to solve actual problems. The distinction between basic and applied research is often marked by the creation of a new project to explore promising results of a basic research programme (moving from a long-term to a medium-short term perspective in the exploitation of the results). The results of applied research are intended primarily to be valid for possible applications to products, operations, methods or systems. Applied research gives operational form to ideas.

● **Experimental development**

Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improving existing products or processes (OECD, 2015). The development of new products or processes qualifies as experimental development if it meets the 5 core criteria for identifying R&D activity.

● **Criteria for classification as R&D activities**

For an activity to be considered as an R&D activity (OECD, 2015), it has to be:

- novel (i.e. To be aimed at new findings) ;
- creative (i.e. To be based on original, not obvious, concepts and hypotheses) ;
- uncertain (i.e. To be uncertain about the final outcome) ;
- systematic (i.e. To be planned and budgeted) ;
- transferable and/or reproducible (i.e. To lead to results that could be possibly reproduced).

As indicated above, the key criterion for classification of R&D activity (Basic research, Applied research, Experimental development) is the expected use of results. However, two practical criteria are bound to these activities, leading to two questions:

- How far ahead in time is the activity likely to lead to results that can be applied ?
- How broad is the range of potential fields of application for the results of the R&D activity (knowing that the more fundamental the research, the broader the potential field of application) ?

All these characteristics have been considered and used for the prioritisation of the research actions of the Strategic Research Agenda. However, temporality of R&D activities doesn't mean that the process is simply linear with basic research leading to applied research and then to experimental development. Many flows of information and knowledge are possible in several directions in the R&D general process: experimental development can inform basic research, basic research can lead directly to new products and processes (OECD, 2015).

Lastly, in particular when dealing with different scientific fields (multidisciplinary topics), in order to avoid misunderstanding it can be useful to classify R&D activities according to the knowledge domain in which it is conducted (e.g. natural sciences, engineering, technology, social sciences…) (OECD, 2015). The 6 strategic stakes expressed in the call topic MG-2-10-2020 (i.e. Changing demand, Social changes, Climate, Biodiversity, Digitalisation) are useful in that aim.

2.3.6. Emergence of themes

Incidentally, the processing of the large quantity of PIRs revealed the existence of some major recurring concerns as a background through all the raised issues. The overall picture reveals the reality of diverse major concerns for stakeholders today. In order to provide stakeholders with familiar reference points in reading all research actions, it has seemed important to take this fact into account and to build on it in the construction of the strategic research agenda. Moreover, these elements feed directly into the BISON SRDA and complement it with an increased level of detail for specific research topics.

Hence, a series of 15 themes has been identified and defined for the further characterization of research actions. The scope of all these themes has been tested through exchanges (consultation sessions) with multiple interlocutors along the process of Step 3, clarified where necessary and confirmed, leading to the final definitions provided in Table 4. Four of them are related to the improvement of the general process of transport infrastructure project development (blue shade). Two are related to the contribution of stakeholders in projects (pink shade). Two are related to the improvement of the mitigation hierarchy (grey shade). Two are related to the great environmental challenges protecting biodiversity has to face today (yellow shade). Lastly, five themes are related to the solving of specific questions posed by transport infrastructures to biodiversity (green shade).

Table 4. Themes identified through the process for the classification of research actions

Theme title (code)	Definition
Policy (POL)	Improve policies in order to ensure that biodiversity care guidance is properly targeted in transport infrastructure projects, from the decision-making stage and throughout the whole life of infrastructures
Law and regulation (LAR)	Improve laws and regulations in order to ensure that rights and duties of all stakeholders relative to biodiversity care are properly applied in transport infrastructure projects, from the decision-making stage and throughout the whole life of infrastructures
Planning of TI projects (PLP)	Improve the planning process in order to ensure that the status of biodiversity and its protection objectives are properly taken into account during the process, and will continue to be considered during and after infrastructure construction
Assessment of realised TIs (ASR)	Improve the process for assessing the effects of realised transport infrastructure on biodiversity, and for checking compliance with their biodiversity commitments.
Cooperation between TI stakeholders (COS)	Improve the process of cooperation between stakeholders (solving breaks, developing levers) in order to reach the maximum benefit for biodiversity care, from the decision-making stage and throughout the whole life of infrastructures
Awareness of TI stakeholders (AWS)	Improve awareness of all types of stakeholders on the diverse dimensions of biodiversity-friendly transport infrastructure in order mutual understanding lead to shared involvement for biodiversity
Reduction measures (REM)	Assess and improve the ecological relevance and effectiveness of reduction measures of transport infrastructure effects on biodiversity, and develop better solutions for biodiversity in this field.
Compensation measures (COM)	Assess and improve the ecological relevance and effectiveness of compensation measures of transport infrastructure effects on biodiversity, and develop better solutions for biodiversity in this field
Responses to effects of climate change (CLC)	Identify and understand all the phenomena due to climate change affecting biodiversity in infrastructure, their foreseeable effects and develop mitigation solutions, as well as nature based solutions against climate change
Responses to spread of invasive species (IAS)	Identify and understand all the phenomena bound to spread of invasive species in infrastructure, their foreseeable effects and develop mitigation solutions, as well as nature based solutions against dispersal of invasive species
Achieving ecological permeability of TIs (EPE)	Identify and understand the different aspects of the barrier effects caused by infrastructure on populations and develop solutions to restore ecological permeability by means of resources from all relevant fields
Restoring and enhancing ecological networks with TIs (REN)	Understand and improve the ecological potential of transport infrastructures and their associated raw-material production sites in order to make them contribute to restore blue and green networks and enhance their ecological functioning
Achieving TI network densities compatible with ecological capacities/interest (TIN)	Understand the various effects of transport network density and use intensity of infrastructures on population dynamic and ecological functions and services at landscape scale, in view to adapt transport development to landscape ecological capacities and interest
Controlling the specific pressures on biodiversity created by the transport sector (SPR)	Identify and understand the various effects on biodiversity due to the pressures specifically created by transport the transport sector (infrastructures and their use) and develop targeted mitigation solutions
Developing the biodiversity care culture in the transport sector (CAC)	Identify and understand all the breaks and possible levers for the diverse stakeholders' cultures regarding biodiversity-friendly attitude in order to develop and generalise a pro-biodiversity behaviour in the transport sector

2.3.7. Prioritization parameters of RAs

From the scientific point of view, the way to put a research action on the research agenda depends on 3 parameters that are the relevance of the action towards the topic (i.e. more or less important to make significant progress), the expected effort of research anticipated to complete the given research (i.e. the size of the gap to fill which determines means and time to reach the goal), and the urgency to get answers from the given action to respond to society expectations or needs. The latter determines when to start the action and indicates with which intensity it should be developed.

Systemic rational approaches have been adopted to set the Relevance level and the Effort level of each RA. They are described below. Before adoption, in order to assess their rightness, their results have been compared to the comments, ranking and votes provided by the all the persons consulted along the process. Partners of WP4 involved in this ranking were D. François (UGE), Ondine Deyrieux (OFB), Nicolas Hette-Tronquart (OFB) and Ivo Dostál (CDV). Providing an objective measure of urgency is tricky, as several value systems come into play and their relative weight varies greatly from one person to another and from one type of stakeholder to another. Ultimately, appraisal of the degree of urgency depends very much on political choices, which ultimately will determine the decision to launch a particular action. Attempting to define urgency at this stage has seemed illusory and pointless.

- **Relevance parameter**

The whole process of consultation from the initial list of PIRs (Figure 14) has been designed to identify the relevant research actions to be developed now-on for biodiversity-friendly transport infrastructures. Points of views from various types of stakeholders gathered along the process (comments, rankings, votes) have been used and analysed to progressively confirm the relevance level of RAs. Irrelevant and low-relevance proposals have been gradually eliminated from the list until the very last step. This concerned notably some actions that pertain to the field of deployment (i.e. after the R&D activities and that are taken into account in other work-packages of BISON). This regard also some proposals for implementation of specific tools that would be necessary to more efficiently carry out research for transport ecology in Europe. Although not research actions, the latter have been integrated in a dedicated section of the strategic research action programme (see Section 3.4).

The level of detail on the information collected on relevance of RAs through the process made it possible not just to discriminate low relevance proposals, but also to distinguish between two levels of relevance among RAs for the strategic agenda: high or medium.

- **Effort parameter**

The ability to complete a research action depends on three essential conditions. The central condition is the existence of data to address the question. If so, the downstream condition is the existence of a data processing method. If not, the upstream condition is the existence of a method for producing the data. "Method of producing data", "Data" and "Method of processing data" must be understood in the broad sense, whatever the discipline concerned. The pre-existence or not of these conditions will determine the research effort to carry out a given research action (Do the data exist? Does the method to treat data exist to answer to the question? If necessary, does the method to produce these data exist?). Is it necessary to develop specific methods to get and/or treat the data? Or is it possible to use

pre-existing ones? The situation of each RA with respect to these conditions today has been analysed in order to characterise the research effort implied by each one. Table 5 shows the different possible combinations of conditions and the resulting expected research effort - Low (L), Medium (M), High (H-) and Very High (H+) – which is proportional to the number of lacks to overcome (0, 1, 2 or 3 negative answers).

Table 5. Research effort estimation grid

Pre-existing method to produce the data	Pre-existing data	Pre-existing method to process data	Research effort	Comment
Doesn't apply	+	+	L	As data can be directly obtained, the question on method to produce them doesn't apply. This kind of RA just need to get the pre-existing data and process them with an already known method
Doesn't apply	+	-	M	Same as above for data, but the need to develop an original method to process data.
+	-	+	M	This kind of RA can adopt a pre-existing method to produce its necessary data and to process them
-	-	+	H-	This kind of RA needs an original method to be developed to produce its necessary data
+	-	-	H-	This kind of RA can adopt a pre-existing method to produce its necessary data but needs an original one to process them
-	-	-	H+	This kind of RA needs original methods to be developed to produce its necessary data and to process them

3. RESEARCH ACTIONS FOR THE STRATEGIC EUROPEAN AGENDA

This section sets out all the research actions (RA) identified as needing to be carried out in the coming years, and as such constitute the strategic research agenda for biodiversity-friendly transport infrastructures in Europe. Then analysis of all these RAs reveals the existence of 14 major problematics within which they are distributed. The main features (and learnings) revealed by the vision of the whole research actions (i.e. the SRA) are then presented.

In addition to the identification of research needs, the process developed in WP4 has also highlighted the need to implement certain study tools to improve the effectiveness of transport ecology research in Europe. These are not research actions but tools for research which deserve to be presented here as their existence would enable the proposed research actions to be implemented more effectively. Essential to guiding all R&D activities, but to be shared with all stakeholders in order to work in the same direction at all levels, is the need to establish a common understanding of what biodiversity-friendly transport modes and infrastructures must be.

3.1. Research actions (RA) through major problematics

The list of research actions resulting from the whole process is presented below. The analysis of the links between these RAs revealed 14 major problematics to which each of them is bound:

1 Disturbances experienced by species in the vicinity of transport infrastructures ;
2 Risk management to curb impacts bound to wildlife movements;
3 Assessment of crossing systems for optimal deployment;
4 Efficiency and consolidation of impact reduction measures;
5 Efficiency and perspectives for solutions at a distance;
6 Overall pressure to biodiversity from transport infrastructures in space and time;
7 Considering all landscape dynamics in transport infrastructure projects;
8 Involving stakeholders of the crossed territories;
9 Optimising the ecological potential of rights-of-way;
10 Mastering the spread of invasive alien species;
11 Adapting to climate change impact ;
12 Characterising biodiversity-friendly performance for continuous improvement;
13 Mastering monetary and non-monetary costs borne by biodiversity;
14 Consistent framework of objectives and principles for coordinated initiatives.

For each RA is specified the time horizon needed to complete it, which is proportional to the requested research effort (cf. § 2.3.7), with four levels, equivalent to 5, 10, 15 and 20 years. Then are specified the types of infrastructures that concerned by the RA, then the stages of the life cycle of infrastructures, then the themes the RA is linked to (cf. § 2.3.6), and lastly the great stakes mentioned by the EC in the topic MG-2-10-2010 (original call).

- **Horizon caption**

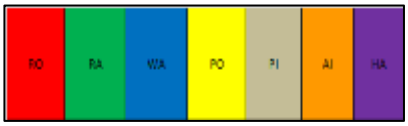
The horizon time (research effort needed) is as indicated below:

- Short term, 5 years (low effort)…… 
- Medium term, 10 years (medium effort)……. 
- Long term, 15 years (high effort)……. 
- Longer term, 20 years (highest effort)…… 

- **Infrastructure caption**

The colour code of each type of infrastructure concerned by the RA is as indicated below:

- Roads (RO): red
- Railways (RA): green
- Waterways (WA): blue
- Power lines (PO): yellow
- Pipeline (PI): grey
- Airports (AI): orange
- Harbours (HA): purple



- **Life stage caption**

The colour code of each stage of infrastructure's life cycle is as indicated below:

- Planning (PLA): orange
- Design (DES): pink
- Construction (CON): yellow
- Adapting (ADA): green
- Operating (OPE): blue
- Decommissioning (DEC): purple

● **Theme caption**

Some research actions are bound to a specific theme but, due to the complexity of issues of biodiversity-friendly transport infrastructure, often research actions are bound to two or more themes. Thus, the themes should not be seen as boxes between which the various research actions should just be arranged. These are poles of concern in relation to which each research action is situated. For reasons of clarity in the strategic research agenda, it has been decided to not specify more than 3 themes to a research action. Hence, each RA is linked to three themes at the maximum, among:

- Policy (POL)
- Law and regulation (LAR)
- Planning of TI projects (PLP)
- Assessment or realised TIs (ASR)
- Cooperation between TI stakeholders (COS)
- Awareness of TI stakeholders (AWS)
- Reduction measures (REM)
- Compensation measures (COM)
- Responses to effects of climate change (CLC)
- Response to spread of invasive species (IAS)
- Achieving ecological permeability of TIs (EPE)
- Restoring and enhancing ecological networks with TIs (REN)
- Achieving TI network densities compatible with ecological capacities/interest (TIN)
- Controlling the specific pressures on biodiversity created by the transport sector (SPR)
- Developing the biodiversity care culture in the transport sector (CAC)

The colour code of each theme is the one introduced in Table 4.

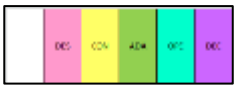
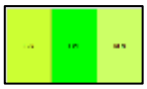
● **Stakes caption**

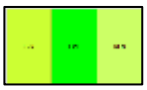
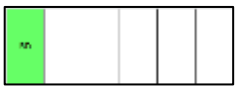
The colour code of each great stake of the original call concerned by the RA is as indicated below:

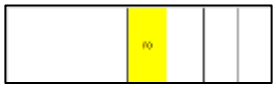
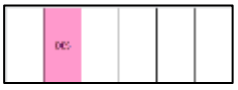
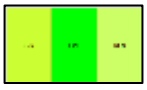
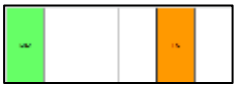
- Biodiversity (BD): green
- Climate change (CC): yellow
- Social changes (SC): pink
- Changing demand (CD): blue
- Technology (TC): orange
- Digitalisation (DG): purple

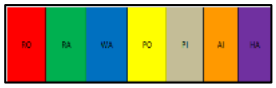
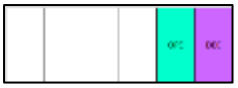
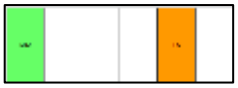
3.1.1. Disturbances experienced by species in the vicinity of transport infrastructures

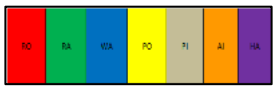
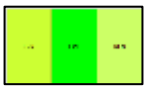
Transport infrastructures and their use produce disturbances of various kinds (physical and chemical). Some of them escape human perception and consequently have so far been neglected from the point of view of the consequences they may have on certain wild species (animal and plant). In order to measure the true impact of transport infrastructures on biodiversity and to know how to remedy it, it is necessary to know the sensitivity of the various species to these disturbances. This would allow to assess their species tolerance to these disturbances and the effects at the individual level as well as at the population level (multigenerational and landscape-scale effects).

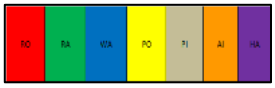
1.1	Evaluate the disturbing effects of noise characteristics (intensity, frequency) on terrestrial, aquatic and flying fauna species, in order to identify and develop the necessary prevention/remediation measures for all IT and vehicles (design and use) and to avoid impact on ROW hosting capacity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

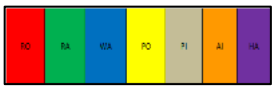
1.2	Evaluate the disturbing effects of artificial light characteristics (intensity, frequency) on terrestrial, aquatic and flying fauna species, in order to identify and develop suitable prevention/remediation measures for TIs and vehicles and to avoid impact ROW hosting capacity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

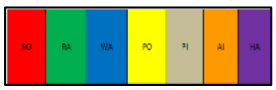
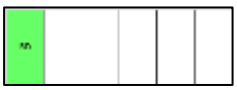
1.3	Assess physical, electrical and electromagnetic effects of powerlines on species, in order to develop suitable prevention/remediation measures and to avoid impact on ROW hosting potential.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

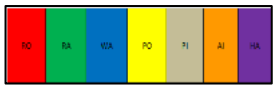
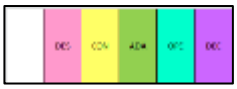
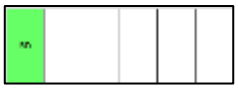
1.4	Assess and take advantage of the potential of research in ecotoxicology and plant health, in order to contribute to in-depth diagnosis of TIs' effects on ecosystems (capture of weak signals in particular).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

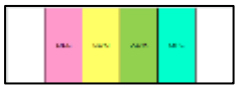
1.5	Evaluate the disturbing effects of vibrations' characteristics (intensity, frequency) on fauna (terrestrial and aquatic) and flora, in order to identify and develop suitable prevention/remediation measures for TIs and vehicles and to avoid impact on ROW hosting capacity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

1.6	Develop knowledge on ecological needs, sensitivity and behaviour of species (including their capacity to adapt) towards disturbances generated by TI in the landscape/neighbourhood, in order to adopt the best fitted avoidance/reduction solutions to the actual impact suffered by the species according to their vulnerability.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

1.7	Assess the real ecological cost (e.g. harm due to feeding or reproduction difficulties, diseases...) suffered by species that seem to adapt to the presence of TIs, in order to identify possible important delayed impacts on these species.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

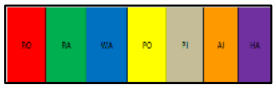
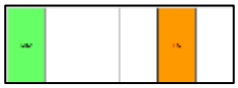
1.8	Explore signals/pressures out of human perception (infra/ultrasounds, electromagnetic waves, release of molecules from materials and wastes...) created by TIs, their use, circumstances, in order to identify possible hidden disturbances on species and biotopes.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

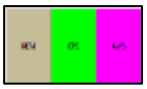
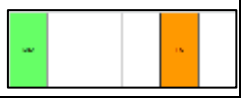
1.9	Identify the resilience of species to disturbance created by TIs and their use (noise, vibration, light, electromagnetic waves, odours, chemicals...) in order to set operational exposure thresholds.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

1.10	Identify the boundary between the warning/hazard preventing effect TI disturbances (noise, vibration, light, electromagnetic waves, odours, chemicals ...) can play on wildlife and the profound disruptive impacts they can cause to its ecology and life cycle, in order to adjust management and reduction measures to avoid deep irreversible impacts.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

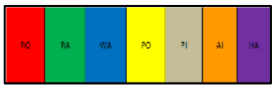
3.1.2. Risk management to curb impacts bound to wildlife movements

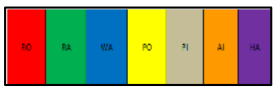
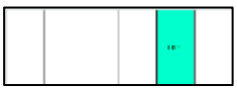
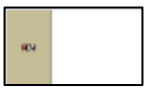
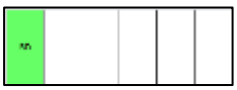
Controlling the crossing problem posed to the various animal species (terrestrial, aquatic, flying) by transport infrastructures requires knowledge of their behaviour when confronted with this problem. This concerns disturbances caused by fixed elements (power lines, pylons, locks, tracks, etc.) and those created by vehicles (land, boats, planes). This knowledge would make it possible to identify the most effective solutions to avoid blockages and prevent/reduce collisions, by seeking them as much in the adaptation of infrastructures as in the adaptation of their mode of operation and changes in user behaviour.

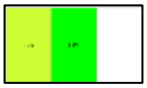
2.1	Develop a method for operators to reliably monitor the movements of various animal species (at least key species) around and across TI, in order to generalise reliable reporting of situations and initiatives, to improve solutions and feed into research.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

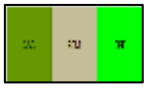
2.2	Assess the potential of automatic detection systems (for presence/movement in the vicinity of TIs), in order to develop solutions to prevent collisions with fauna (with or without human action).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

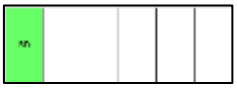
2.3	Identify the typical features of collision risks considering TIs, wildlife species, contexts and circumstances, to serve as a basis to guide the development of more efficient solutions.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

2.4	Develop operational solutions, whatever the type of lever used (technology, ecological engineering, socio-psychology, law...) intended to remove barriers to the migration of terrestrial, aquatic and flying species (long-distance migratory species as well as local species) as part of TI and worksite management.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

2.5	Carry out back analysis of wildlife behaviour observation in the vicinity of TIs in the past decades in order to assess how knowledge was integrated in decision-making for TI projects.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

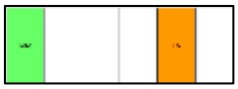
2.6	Understand how the various species react to danger in order to take it into account for setting the design of infrastructures and operating conditions to prevent/reduce collision risk (e.g. speed reduction, visibility…).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

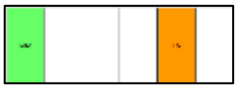
2.7	Assess the ability of all types of levers (social, psychological, technical, economic, ecological, etc.) and their possible combinations to reduce wildlife collisions.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

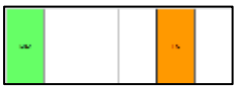
2.8	Analyse the feasibility of traffic-free periods for TI during wildlife migration (taking into account all relevant fields), aiming to reduce impacts on the movement of migratory species.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

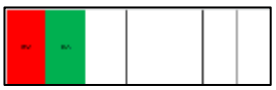
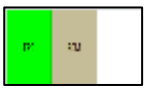
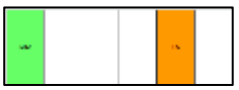
3.1.3. Assessment of crossing systems for optimal deployment

Since their invention, wildlife crossing passages (including associated fencing systems) have been developed following a variety of approaches which have resulted in a wide variety of options. It is now necessary to shed light on the investment choices towards the most effective options from an ecological point of view (defragmentation of populations), particularly with a view to their optimal deployment on a European scale and also for the improvement of existing devices. The analysis of the monitoring data collected on the entire park of fauna passages and their environment across Europe should make it possible to meet this need.

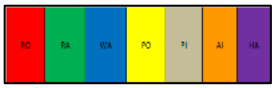
3.1	Carry out large scale feedback analysis of the fencing + fauna passages systems on wildlife actual movements, in order to identify the most efficient design to achieve ecological permeability of TIs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

3.2	Establish pros and cons of (a) wildlife crossings that do not alter the natural topography and soil versus (b) above and below ground wildlife crossings (bridges, tunnels), in order to inform the choice of the most efficient investments for ecological permeability of TIs at large scale.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

3.3	Establish pros and cons of (a) using standard (to be defined) versus (b) site-specific designed (prototype) wildlife crossings in order to reach effective ecological permeability and to inform the choice of the most efficient investment at large scale.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

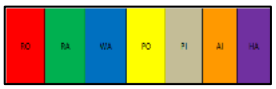
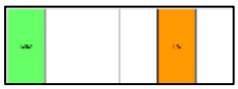
3.4	Establish pros and cons of (a) specific versus (b) broad-spectrum wildlife crossings, in order to ensure efficient ecological permeability of TIs and to inform the choice of the most efficient investment at large scale.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

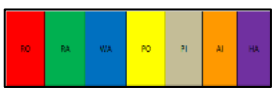
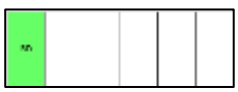
3.5	Develop adaptative solutions for equipments and organisation (regarding all relevant stakeholders) aiming to make pre-existing wildlife and non-wildlife passages more suitable to safe fauna crossing.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

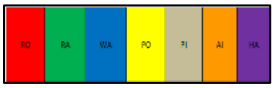
3.6	Identify the needs of all wildlife groups with regard to the ecological permeability of the different types of TIs as well as their preference towards types of crossing devices in order to build a common sizing methodology adaptable to the diversity of territories (necessary density of crossing devices for target species, type and location).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

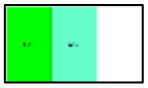
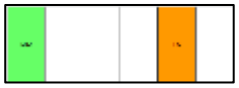
3.1.4. Efficiency and consolidation of impact reduction measures

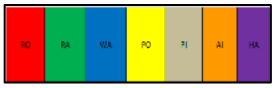
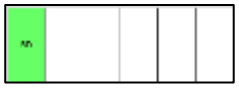
The history of measuring the effects of transport infrastructure on biodiversity (in particular through regulatory monitoring data) accumulated over decades, now offers the possibility of characterizing the real effectiveness of the various reduction measures implemented, especially in the long run. This analysis would make it possible to rank reduction measures in terms of effectiveness, to identify areas for improvement, to characterise the influence of the context of use on their effectiveness, to identify the appearance of unforeseen phenomena in the behaviour of species or the evolution of populations. It would also make it possible to consolidate or improve the monitoring protocols (criteria, methods) of the future measures implemented.

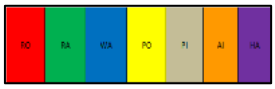
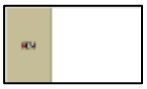
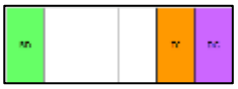
4.1	Evaluate all types of reduction measures used to date, in order to inform in a transparent way about their ecological effectiveness, about their capacity to provide reliable data to improve knowledge, and to identify the needs for improvements on both aspects.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

4.2	Define shared criteria and methodology to assess the effectiveness of the different types of reduction measures as well as proposed innovations, in order to allow reliable, fair and transparent appraisal to all stakeholders (common reference and requirement system).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

4.3	Develop monitoring protocols that can evolve over time, in order to allow adjustment of methods to the evolution of results produced by reduction measures over time.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

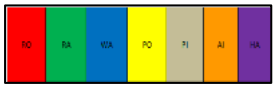
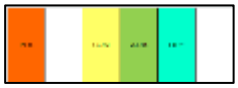
4.4	Compare the different solutions (methods and technologies) available today to assess population dynamics and functional/genetic fragmentation on both sides of TI, in order to identify the most appropriate for research, for operational diagnosis and monitoring, and to serve as base for possible improvement efforts.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

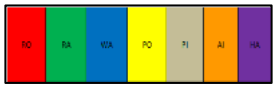
4.5	Set sound and shared general principles for the identification of the most relevant (key) species to be monitored as part of the routine monitoring of TIs (e.g. among threatened, common, umbrella species...) in the various ecosystems across European biogeographical contexts.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

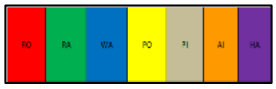
4.6	Define the criteria for the selection of the most appropriate reduction measures to be applied according to the type of TI and the ecosystems crossed, as well as their recommendations for monitoring.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

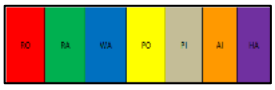
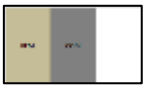
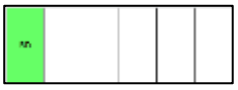
3.1.5. Efficiency and perspectives for solutions at a distance

In certain contexts and circumstances, the preservation of species near transport infrastructures may not be achievable through impact reduction measures, either temporarily (construction phase) or permanently. The decision to treat the problem at a distance, either temporarily (temporary translocation) or definitively (compensation provided for by the mitigation hierarchy) must follow transparent common rules based on scientifically based arguments and principles. With regard to compensation, which on a strictly ecological level is particularly difficult to carry out, it is necessary to establish the ecological and economic balance sheet of all the experiments carried out so far in Europe. This knowledge would make it possible to shed light on the prospects for the development of the concept in a European context of growing competition for the use of land.

5.1	Evaluate the benefit and applicability of species translocation from TI worksites, aiming at their safeguarding, reproduction and reintroduction in the landscape.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

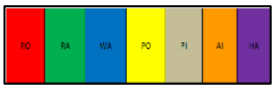
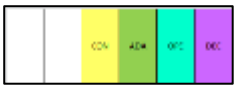
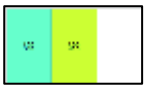
5.2	Realize a feedback of the concept of compensation (real conditions of implementation and real ecological results), in order to evaluate its ecological effectiveness and to anticipate its future applicability in Europe with respect to the evolution of land use issues.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

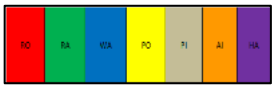
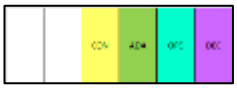
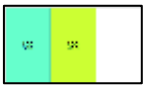
5.3	Carry out large scale cost-benefit analyses from the ecological point of view of past projects regarding compensation/restoration measures and avoidance/reduction measures, in order to compare approaches and inform future decision-making.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

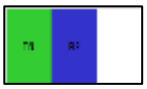
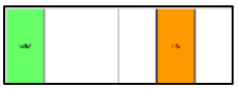
5.4	Define the contexts, circumstances and threshold values of threats, for which keeping away/moving species outside the area of influence of the TI is a preferable strategy than reduction measures, in order to provide a more efficient protection of species (avoidance of excess mortality, trapping, contamination, etc.) and to inform decision-making for compensation measures.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

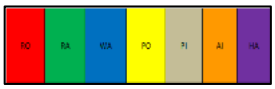
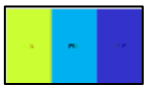
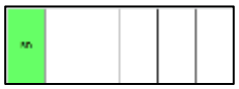
3.1.6. Overall pressure to biodiversity from transport infrastructures in space and time

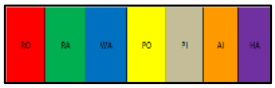
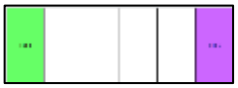
Different types of transport infrastructure produce different types of effects on species and natural environments. Similarly, infrastructures of different sizes and whose mesh is more or less dense, will have more or less marked effects, in intensity, spatially and over time. With a view to new projects or increasing the capacity of existing infrastructures, it is important to know the resilience capacity of the different types of natural environments with respect to the disturbances inherent in the various types of infrastructure (nature, size, mesh). The question concerns direct effects but also the indirect effects (potential of the projects to accelerate the artificialisation of the surroundings and to facilitate the accessibility to the natural areas).

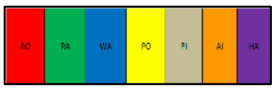
6.1	Set shared reliable methods and metrics for the monitoring effects on biocenoses (impact on diversity and abundance, recovery) of TIs through all their life stages.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

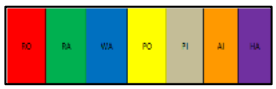
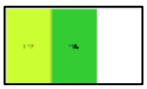
6.2	Set shared reliable methods and metrics for the monitoring of effects on biotopes (impact on substrate and microclimate characteristics, recovery) of TIs through all their life stages.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

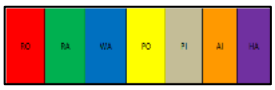
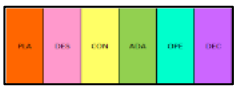
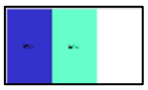
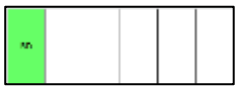
6.3	Establish pros and cons for biodiversity of (a) bundled TI in corridors vs. (b) scattered TI across land, in order to inform decision making on land planning for biodiversity protection.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

6.4	Analyse the relationship between the characteristics of the different types of TIs in terms of dimensions, flow, speed... and their direct and induced effects on biodiversity (e.g. through land use, resource consumption, disturbances created to wildlife and ecosystems...) in order to inform transport policy, planning and decision making.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

6.5	Analyse the spatial extent of impact on biodiversity of the different types of TIs throughout their life, in order to estimate their relative pressure on biodiversity, to inform the application of principles of avoidance (future projects) and reduction, and set realistic management objectives for biodiversity protection.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

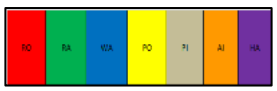
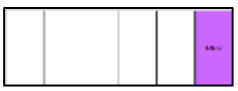
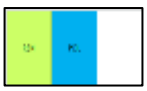
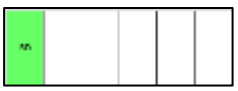
6.6	Identify threshold values for some characteristics of TI (mesh density, flow rate, type, size, etc.) beyond which survival of biodiversity of the concerned areas is compromised (disappearance of particular species, degradation of biocenoses and biotopes).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

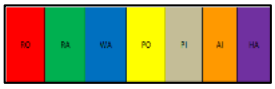
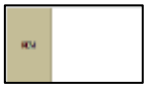
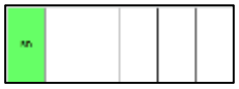
6.7	Identify and set threshold values for disturbances caused to biodiversity by transport infrastructures (through direct and induced effects), beyond which the conservation of biodiversity is compromised in the surroundings, in order to control the extension and the use of transport networks.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

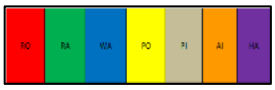
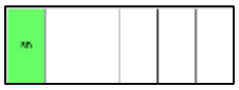
6.8	Develop a comprehensive and consistent assessment framework for TI, addressing all life stages, in view to anticipate direct and induced, delayed, cumulative impacts of projects on biodiversity, as well as to monitor the effects of operational TIs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

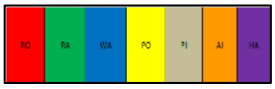
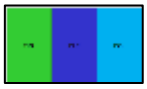
3.1.7. Considering all landscape dynamics in transport infrastructure projects

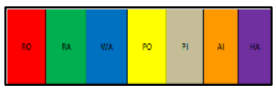
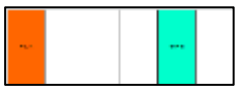
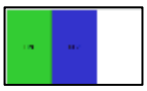
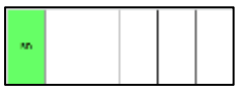
Infrastructure projects affect biodiversity directly, but also indirectly through the various landscape dynamics that they change in the crossed territories (urbanization, agriculture, natural areas, etc.). By planning and designing new infrastructures using a systemic approach at the scale of the crossed territories, it would be possible to prevent the accumulation of negative effects of sectoral approaches. It would also be possible to identify cooperative impact reduction solutions that are more ambitious and more effective from an ecological point of view and more satisfactory from a socio-economic point of view. This territorial approach (integrated planning) opens up possibilities for synergy with local actors for long-term actions in favour of biotopes, biocenoses and local ecological networks.

7.1	Identify and quantify all direct and induced benefits for wildlife and humans (natural habitat, ecological conservation, ecosystem services, resource saving….) offered by decommissioned sections of all types of TIs in order to support their protection/management policy.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

7.2	Develop a methodology for a systemic approach of reduction measures at landscape scale, in order to provide a comprehensive solution to the various effects produced by TIs in space and time (direct, induced, combined).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

7.3	Define the nature, extent of improvements and conditions, for existing TIs be able to provide support to local biodiversity in areas/landscapes degraded by various other causes, in order to set realistic objectives to biodiversity-friendly management of TIs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

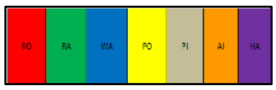
7.4	Define criteria and a method to determine the sustainable conditions of human presence (direct disturbing effects; induced effects like artificialisation) with respect to the resilience of different kinds of ecosystems/habitats/biocenoses/species, in order to adapt land planning (carrying capacity) and transport policy (accessibility) in the served areas.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

7.5	Set criteria and a method to identify and measure all impacts on biodiversity due to landscape changes and activity development brought by new sections of transport networks, in order to take into account all consequences induced by TI development at landscape scale.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

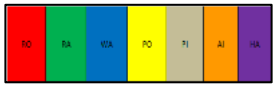
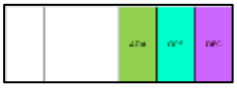
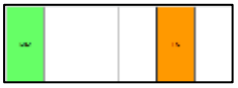
3.1.8. Involving stakeholders of the crossed territories

The good state of local biodiversity is recognized as an important element of the quality of the living environment. As a result, the local actors of the territories can be important allies of the operators in their objective of creating transport infrastructures that respect biodiversity and are capable of providing ecosystem services. This perspective implies, on the part of decision makers and operators, to review the place they give to local actors in the process of decision-making, planning and design of projects and adaptation of existing infrastructures. This revisited involvement of local actors could go as far as cooperation in the maintenance of infrastructures (rights-of-way).

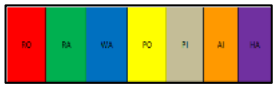
8.1	Develop tools for win-win cooperation between operators and local stakeholders interested in the beneficial use of ROW, in order to implement and generalise a more efficient and biodiversity-friendly management of ROWs.

Horizon	Infrastructures	Stages	Themes	Stakes
				

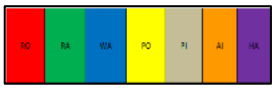
8.2	Assess the ecological and socio-economic advantages and disadvantages of different agro-ecological solutions applicable to the management of transport infrastructures ROW, in order to inform on possible changes of practice in favour of biodiversity that could be considered thanks to collaboration with local stakeholders.

Horizon	Infrastructures	Stages	Themes	Stakes
				

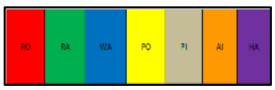
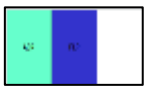
8.3	Identify and assess (benefits and drawbacks) all the levers that civil society can activate in view to stimulate more biodiversity-friendly decision-making and initiatives in the transport sector.

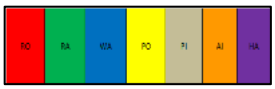
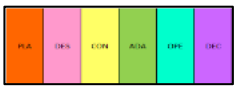
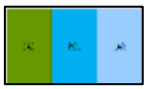
Horizon	Infrastructures	Stages	Themes	Stakes
				

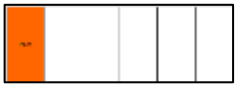
8.4	Develop a method for decision-making that transparently arbitrates between the diverse public stakes related to TI projects and the concerned territories at national and local levels, in order all stakeholders can fairly consider those related to biodiversity.

Horizon	Infrastructures	Stages	Themes	Stakes
				

8.5	Make explicit and measurable all the expected external social benefits (quality, quantity) from a biodiversity preserved within TIs, in order to consider them in a social assessment of the area of ecological influence of TIs.

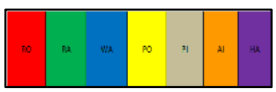
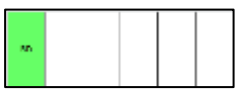
Horizon	Infrastructures	Stages	Themes	Stakes
				

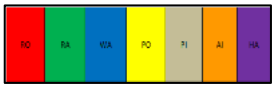
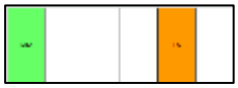
8.6	Identify all the causes that lead to negotiated consent or conflict between stakeholders rather than true consensus to preserve biodiversity in decision-making for TI projects, in order to develop better decision process and integrated planning.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

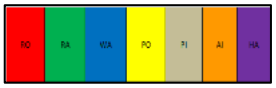
8.7	Develop a method for estimating the "demand/need for transport" extended to all stakeholders of the crossed territories, in order to more realistically dimension the need (qualitatively and quantitatively) and to assess the consistency of projects with the characteristics and the socio-economic and environmental issues (including biodiversity) of the concerned territories (land use prospects).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

3.1.9. Optimising the ecological potential of rights-of-way

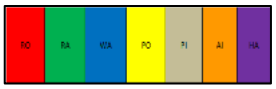
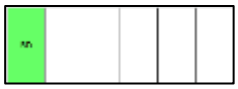
The green areas of transport infrastructure present a potential that is still underused for the preservation of biodiversity and for the provision of ecosystem services. On the one hand, it is necessary to determine the conditions to be met to allow the establishment and survival of a biodiversity compatible with the constraints of operation, maintenance and safety of the various types of transport infrastructures. It also involves solving the problems of changing operator practices aiming to develop and preserve the habitat and connectivity functions of green outbuildings

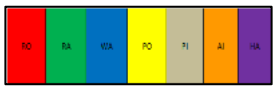
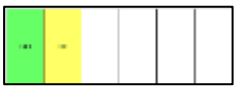
9.1	Define criteria and a method for the assessment of ecological connectivity along ROW of linear TI, in order to measure their capacity to help reweave the crossed green and blue networks and to guide initiatives				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

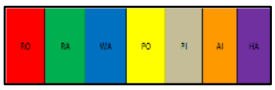
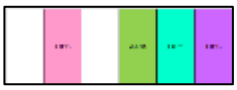
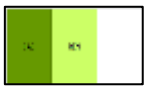
9.2	Identify plant species and their management that match both technical requirements of the diverse types of TIs and relevance for biodiversity care (e.g. hosting capacity for a fauna compatible with transport infrastructure safety) for the various European biogeographical contexts.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

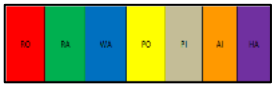
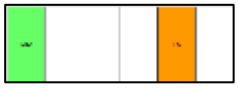
9.3	Identify the determining factors in the colonisation process of habitats located in rights of way of TIs, in order to determine the actions that can be implemented in ROW to promote hosting of local species.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

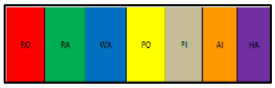
9.4	Develop a methodology for the diagnosis of shipping canals allowing their assessment as aquatic habitat, their longitudinal connectivity for aquatic species and their permeability for terrestrial species (crossing) in order to guide the necessary improvements in design and management.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

9.5	Identify parameters for describing ROW's ability to host biodiversity (e.g. habitat suitability, connectivity suitability…), in order to drive and monitor the improvement of their management for biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

9.6	Develop vegetation management solutions in ROW for optimal benefit to biodiversity while taking into account the context of climate change, so as not to create a risk of fire.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

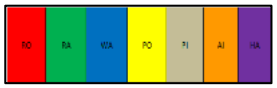
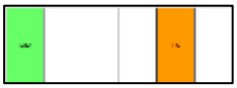
9.7	Identify the levers needed to move from evidences on the ability of ROW to serve as habitat and/or corridor for biodiversity, to the deployment of concrete large-scale actions for the benefit of the concerned biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

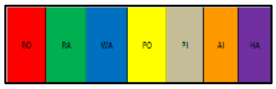
9.8	Set criteria and a method to identify the areas inside transport infrastructure ROW where measures of adaptation, reduction and/or specific management are worth being implemented, in order to make them functional as local ecological network sections.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

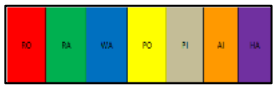
9.9	Set criteria and method for assessing the enhancement of ecosystem services thanks to biodiversity-friendly management of ROW.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

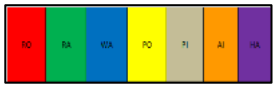
3.1.10. Mastering the spread of invasive alien species

The issue of invasive alien species and transport infrastructure concerns not only the proliferation of these species taking advantage of the habitat provides by rights-of-way, but also the dissemination of these species by vehicles (and their loads) circulating in Europe or entering it (land vehicles, planes, ships). Finding answers to these problems while preserving local biodiversity requires knowing the reproduction processes of invasive species and their modes of dissemination (natural and anthropogenic). Faced with a generalized phenomenon, the implementation of solutions may require the contribution of all the actors concerned (operators, carriers, passengers, traders, customs services, etc.). Specific tools must be developed to enable their participation in understanding and solving the problem (information, monitoring, control, prevention, etc.).

10.1	Develop operational methods for controlling/reversing the dissemination of IAS (flora and fauna) through the different types of transport modes (infrastructures and vehicles) based on disruption of their reproductive cycle, in order to avoid environmental collateral damages and side-effects on native species.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

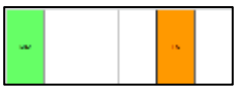
10.2	Develop operational tools for transport operators to diagnose/assess and report (e.g. mapping) on the presence of IAS (flora and fauna) in their network assets, in order to monitor trends across Europe, the effectiveness of action against spread and to adapt control strategies.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

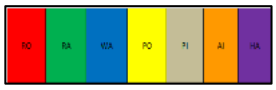
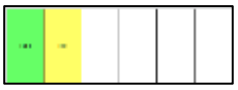
10.3	Identify how the different types of TI contribute to the spread of the various invasive alien species in Europe (flora, fauna), in order to guide the development and implementation of preventive and curative solutions through management and design, notably of ROWs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

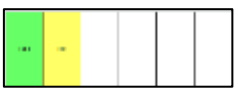
10.4	Define the different ways, conditions and limits to make TI (equipment, vehicles, ROW, management...) favourable to native biodiversity while avoiding the spread of invasive species				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

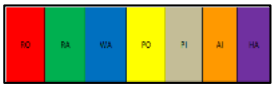
3.1.11. Adapting to climate change impact

Any reflection and action in favour of biodiversity in the field of transport infrastructure must now be done by integrating the major trends induced by climate change, including the displacement of the distribution zones of species towards higher latitudes and altitudes. Regarding the factors of climate change, all transport infrastructures assets (not only their green areas) can develop solutions for the sequestration of greenhouse gases. With regard to the effects of climate change, action must be directed towards solutions for reducing the risks and impacts of extreme events (storms, droughts, fires, etc.) on the species and habitats hosted in the rights-of way and in the vicinity. In this regard, the widespread lack of water in the summer period requires a special effort to develop water management and protection of wetlands and aquatic environments associated with transport infrastructures.

11.1	Develop technical solutions to make water collected on impervious surfaces (e.g. roads, airports, etc.) useful for biodiversity within the ROW and in the surrounding landscape (e.g. rivers, streams, ponds…)				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

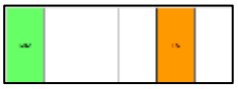
11.2	Develop solutions able to protect biodiversity against impacts of climate change and/or to reduce its effects (e.g. mitigation of extreme temperatures, of high winds, drougth...) thanks to transport infrastructure ROW.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

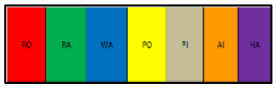
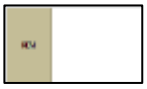
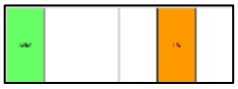
11.3	Anticipate the consequences of climate change on the water regime of navigable rivers and canals (quantity and quality), in order to maintain living conditions and connectivity along hydro-systems (i.e. including connected natural streams).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

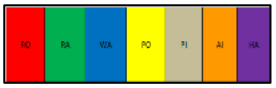
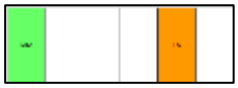
11.4	Develop solutions for TI assets (not limited to ROW) beneficial for biodiversity but also able to counteract the cause of climate change through the reduction and sequestration of greenhouse gases.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

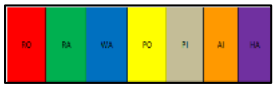
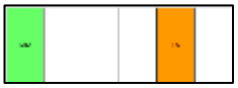
3.1.12. Characterising biodiversity-friendly performance for continuous improvement

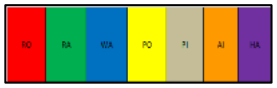
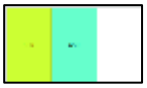
In a process of continuous improvement (cf. EN ISO 9001), it is essential to have a general reference system (method and indicators) making it possible to measure and compare the actual progress and the margins of potential progress of all the initiatives for better consideration of biodiversity. This concerns transport infrastructures throughout their life cycle, equipment, techniques, uses and behaviours of all stakeholders, up to the final choices of users. This general reference system would make it possible to compare fairly and transparently all solutions and initiatives, but also to be able to measure progress on several points for improvement already identified today.

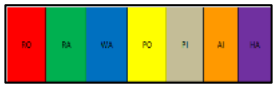
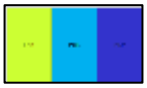
12.1	Develop technical solutions for TIs and concerned vehicles, that prevent and/or mitigate the impact of soil vibrations on sensitive terrestrial, aquatic and flying (e.g. tree nesting) fauna.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

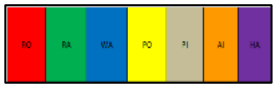
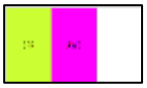
12.2	Compare nature-based solutions and civil engineering solutions applicable to the design, construction and maintenance of TIs as well as to the management of material supply sites, in order to rank their respective technical, ecological and economic interest.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

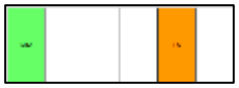
12.3	Develop solutions to reduce the need for materials and energy in the construction and maintenance of TI, in order to reduce the pressure induced on biodiversity at resource supply sites and for maintenance operations.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

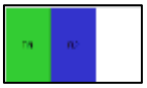
12.4	Develop solutions to reduce pollutant emissions during the construction and maintenance of TIs, in order to lighten the overall environmental pressure on biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

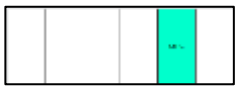
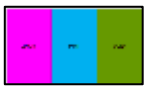
12.5	Assess the impacts on biodiversity of the material supply chains for TI needs at all stages of life, in order to allow a comprehensive assessment of TI projects and operations on biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

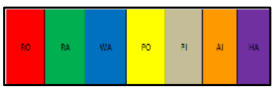
12.6	Set shared criteria for characterizing the specific threats to biodiversity caused by the different types of TIs and assess their specific contribution to the general decline of biodiversity, in order to inform transport policy and planning.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

12.7	Identify and set a limited number of indicators (particular species or other) representative of the specific effects of TIs on biodiversity loss, in order to make all stakeholders perceive their large scale impact on biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

12.8	Assess the direct and induced effects on biodiversity of all types of mobility (vehicles, infrastructures, fuel production and supply) in relation to the type of energy (hydrocarbon, electric, H, biofuel..), in order to inform their relative benefits and drawbacks, necessary improvements and policy choices.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

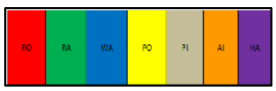
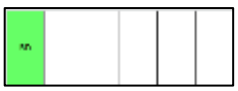
12.9	Estimate the benefits and impacts (direct and induced) for biodiversity expected from the diverse possible modal shifts and combined transports, in order to inform policy choices and incentives in those fields.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

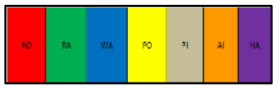
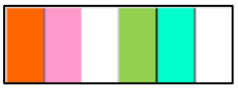
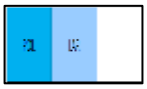
12.10	Develop a formal relationship between the travelled distance (people, goods) and the resulting impact on biodiversity (land use, resource consumption, pollutions, disturbances…) depending on transport modes, in order to inform decision-making (transport policy) and choice at all scales (Europe, local, institutions, individuals) and guide innovation needs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

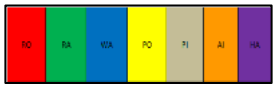
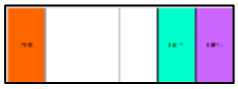
12.11	Develop shared criteria, methodology and reference scale for rating the effective consideration of biodiversity by TIs, operators and technical solutions, in order to inform individual choice and institutional decision-making (policy, regulation).				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

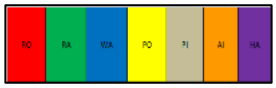
3.1.13. Mastering monetary and non-monetary costs borne by biodiversity

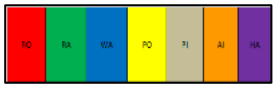
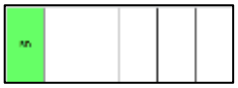
The monetization of certain impacts on biodiversity still raises questions of method and acceptability today. The non-monetization of certain impacts also poses problems of recognition - and therefore of taking them into account - in the decision-making process. These two problems must be clarified and solved jointly because, ultimately, it is essential that all the effects of the same project, monetizable and non-monetizable, be taken into account in an equitable, coherent and transparent way. Progressing along this path makes it possible to lay the foundations for the concrete initiatives necessary in terms of financial compensation for the impacts caused to biodiversity in the field of transport.

13.1	Develop the "disturber-pays" principle and its application tools for the transport sector (following the model of the "polluter pays" principle), in order to stimulate and finance improved practices for biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

13.2	Assess in which way action on transport prices can positively influence the consideration for biodiversity by the various stakeholders.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

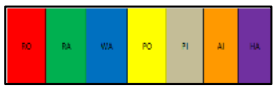
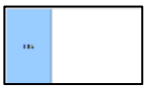
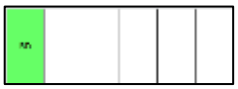
13.3	Develop the most appropriate scales of value (monetary or non-monetary metrics) for the assessment of biodiversity protection and ecosystem services, in order to rationally support the prioritization of impacts and solutions in the TI assessment				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

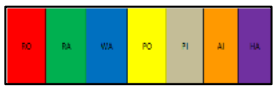
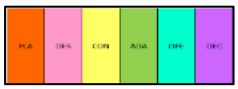
13.4	Develop the understanding, the acceptability and use of non-monetary metrics by all stakeholders in order to better take biodiversity into account in decision processes.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

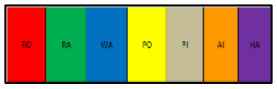
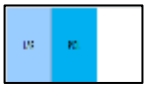
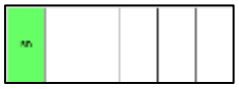
13.5	Develop methodological approaches able to combine monetised and non-monetised parameters of TI project in a balanced way, in order to allow for a comprehensive and fair assessment, especially with regard to biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

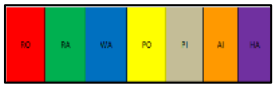
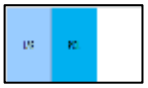
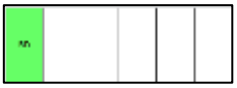
3.1.14. Consistent framework of objectives and principles for coordinated initiatives

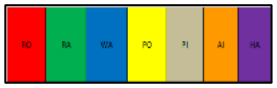
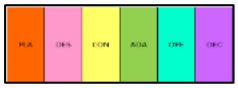
Deploying effective and coherent action to generalize biodiversity-friendly transport infrastructures in Europe requires that, at the most operational level, the stakeholders concerned work in the same direction. Ecological objectives adapted to each area of the territory must be determined and imposed on all initiatives and stakeholders. Furthermore, it is necessary to identify, then remove, any obstacles to this strategy (contradictions, incompatibilities, etc.) contained in the various policies, laws and regulations relating to transport, biodiversity and land use planning, at European level, in countries and across internal borders. It is also necessary to make this strategy take advantage of the great principles developed these last years to support initiatives respectful of the environment.

14.1	Analyse the legal principle of regulatory independence, in order to understand how it may impact cross-fertilization between the environment, transport and land-use planning sectors to achieve biodiversity-friendly TIs.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

14.2	Identify and set clear biodiversity protection objectives applicable to all types of projects in a given area, so that any TI project is informed on the way it must contribute to the area's ecological objectives and its integrated planning.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

14.3	Assess the current public policies concerning each life stages of TI, at European and national levels, in order to identify and correct any points that can be directly or indirectly detrimental for biodiversity.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

14.4	Assess the ability of the anticipation and precaution principles to stimulate or hinder innovative initiatives for biodiversity in the transport sector.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

14.5	Assess laws and regulations concerning each life stages of TI, currently in force at European and national levels, in order to identify and correct any gaps and contradictions that can result in non-optimal consideration for biodiversity by TI projects.				
	Horizon	Infrastructures	Stages	Themes	Stakes
					

3.2. Main features of the strategic research agenda

The main features of the research agenda as highlighted by all the research actions are presented below.

3.2.1. Concerned transport infrastructures

Almost all research actions concern roads and railways (97% and 96% respectively – Figure 15). Airports and waterways are considered second, but with equal importance (88% and 87% respectively). Then come harbours (80%), powerlines (78%) and lastly pipelines (74%). Hence, the vast majority of research actions show that they are not specific to a single type of infrastructure. This happens in only 3 instances: one research action specific to powerlines (RA n°1.3), two research actions specific to waterways (RA n°9.4, RA n°11.3). This makes possible significant cross-fertilization of knowledge between the different transportation sectors. Hence, as an example, roads and railway share 96% of

the research actions (Figure 16). More broadly, roads, railways, waterways, airports and harbours are able to share more than 80% of the knowledge acquired thanks to the proposed research actions. Even the (relatively) least considered infrastructures (powerlines and pipe lines) can share 73% to 77% of the knowledge acquired with the other five.

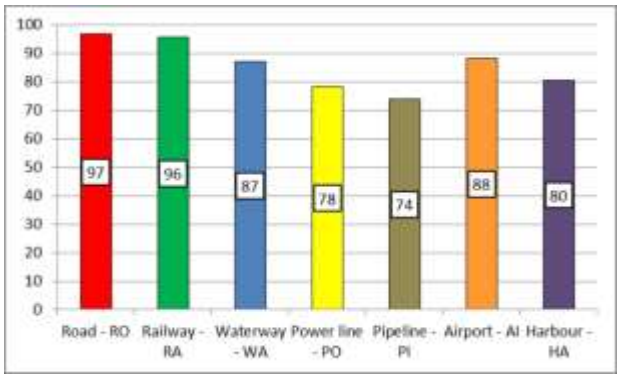


Figure 15.Transport infrastructures concerned by research actions (%)

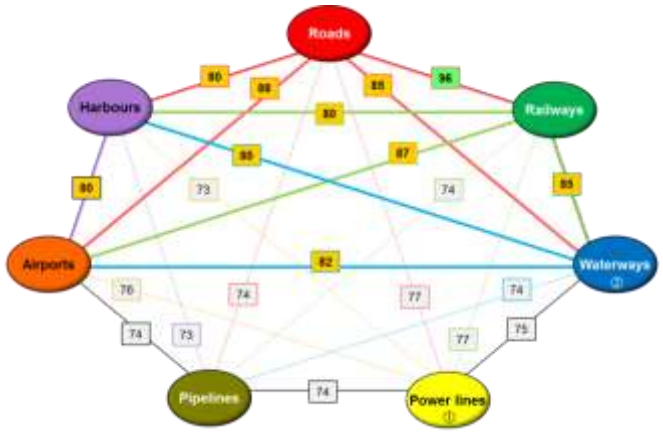


Figure 16. Connection between transport infrastructures within research actions (%)

3.2.2. Life stages

The most considered life stage among research actions is Operating (91% - Figure 17). This attests to the progress still necessary for this stage despite it has been the most taken into account since the birth of road ecology and transport ecology (MELATT, 1985; Forman et al., 2003; van der Ree et al., 2016). The same can be said for Design (79%). Although it entered the field of concerns more recently, the Adapting stage of pre-existing infrastructures now raise also many questions (82%). The questions on these 3 steps are also strongly linked together as shown by the triangle Design-Adapting-Operating on Figure 18: 71% to 77% of research actions share these stages.

Although less numerous, the research actions relating to Planning (51%) and Decommissioning (49%) mark a renewal of research questions. Infrastructure planning is considered from a broad perspective, taking into account all the dynamics of the crossed territories (integrated planning). Decommissioning, on the other hand, has so far been of little concern to stakeholders. The Construction stage, which is very brief in relation to the life of the infrastructure, raises fewer questions (36% of research actions concerned – Figure 17) but following the life cycle analysis approach, it includes notably effects of the distant processes (e.g. material supply) induced by the construction.

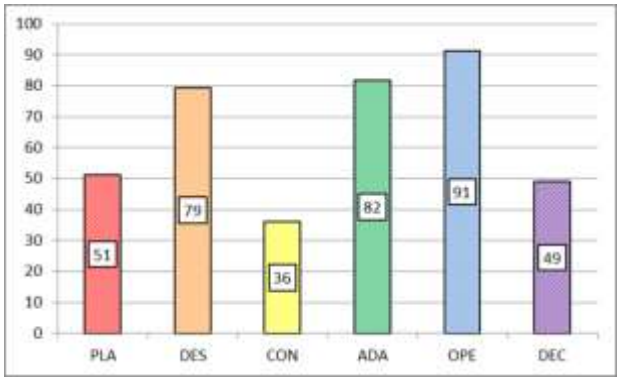


Figure 17. Life stages concerned by research actions (%)

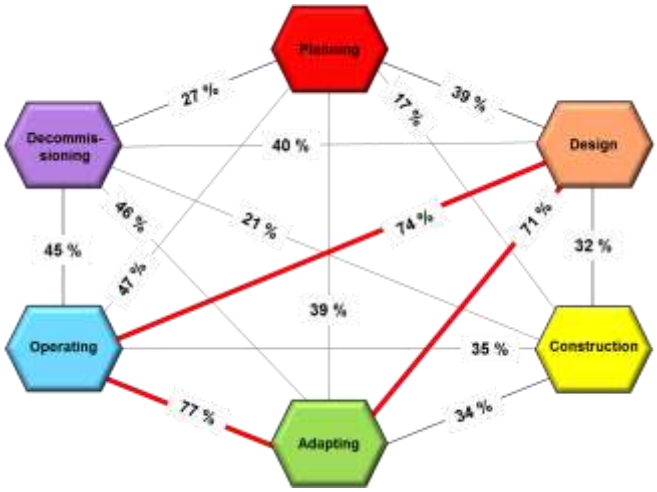


Figure 18. Connection between life stages within research actions (%)

3.2.3. Time horizon to achieve the research actions

Within all the research actions, 16% can be completed within 5 years (Horizon S – Figure 19). Almost half of them (48%) can be achieved in the medium term (Horizon M, 10 years). A third requires long-term work, with 13% requiring more than 15 years (Horizon L+).

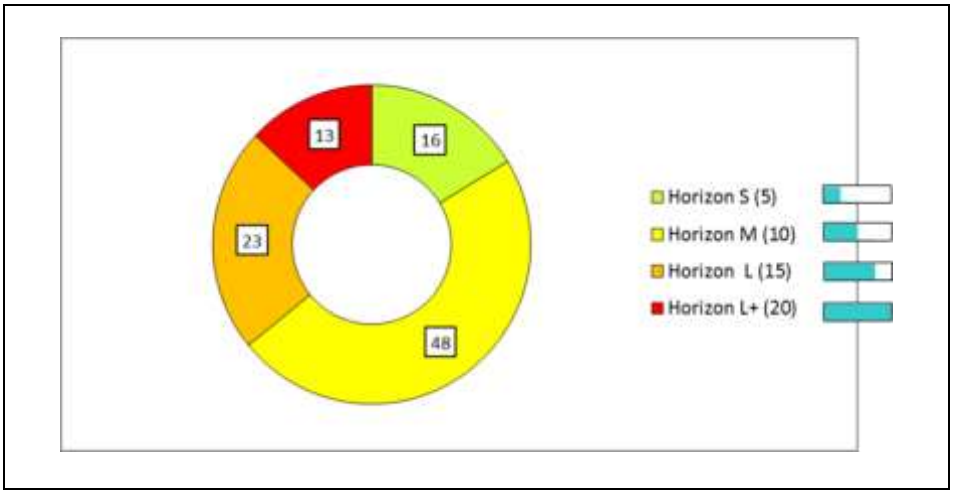


Figure 19. Time horizon necessary to carry out the research actions (%)

Details on the research efforts involved in the research actions for the 14 major problematics are provided in Figure 20 (y axis: Problematic; x axis: Number of research actions). No problematic can be fully addressed in the short term, however problematics N°3 – Assessment of crossing systems and N°9 – Optimising the ecological potential of ROW, both count the higher number of short term research actions (S = 4 for each). Just two problematics gather research actions that can be entirely carried out in the medium term: N°3 and N°13 – Mastering monetary and non-monetary costs borne by biodiversity. The majority of the problematics need long term research to be fully addressed. This is the case for seven of them within 15 years (N°2 - Risk management to curb impacts bound to wildlife

movements; N°4 - Efficiency and consolidation of impact reduction measures; N°5 - Efficiency and perspectives for solutions at a distance; N°9; N°10 – Mastering the spread of invasive alien species; N°11 - Adapting to climate change impact; N°14 - Consistent framework of objectives and principles for coordinated initiatives). Five problematics require longer term (more than 15 years) to be fully addressed: N°1 – Disturbances experienced by species in the vicinity of transport infrastructures; N°6 – Overall pressure to biodiversity from transport infrastructures in space and time; N°7 – Considering all landscape dynamics in transport infrastructure projects; N°8 – Involving stakeholders of the crossed territories; N°12 – Characterising biodiversity-friendly performance for continuous improvement.

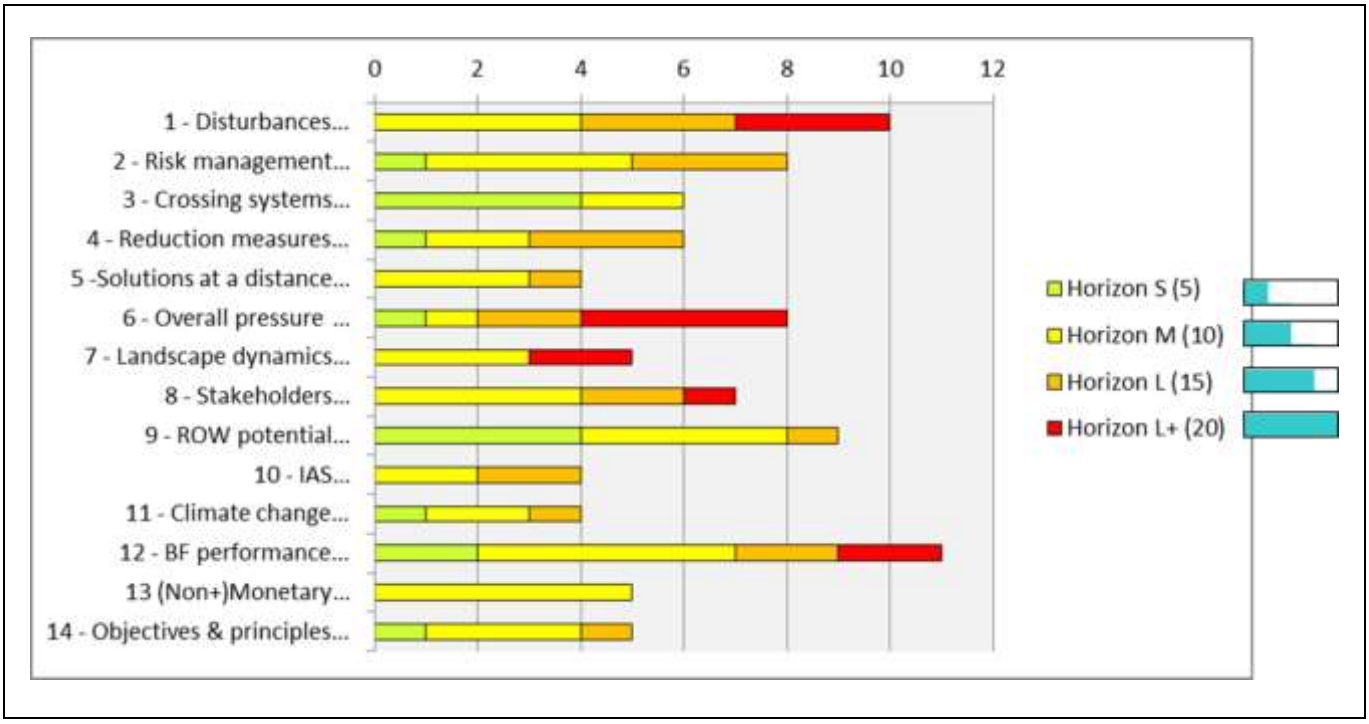


Figure 20. Time horizon necessary for research actions within the various problematics (N)

3.2.4. Relative occurrence of themes among research actions

The relative weight allocated of each theme through the full list of RAs is presented in Figure 21. How each research action is linked to 1 to 3 themes (e.g. RA y and Ra x) has been detailed in Section 3.1.

The most important theme in terms of occurrence are “Reduction measures” (REM = 16%), “Achieving ecological permeability of TIs” (EPE = 13%), “Controlling the specific pressures on biodiversity created by the transport sector” (SPR = 11%) and “Restoring and enhancing ecological networks with TIs” (REN = 11%). Together, these four amount half of all occurrences, which expresses their level of questioning today. Themes REM and EPE are in the heart of the problematics of roads versus biodiversity since it exist (Forman et al., 2003). In many instances they are linked in the same research actions (see Section 3.1). For various reasons, many questions are raised by the solutions brought up to now. Oppositely, themes SPR and REN are more recent and as such, they open up a wide range of questions.

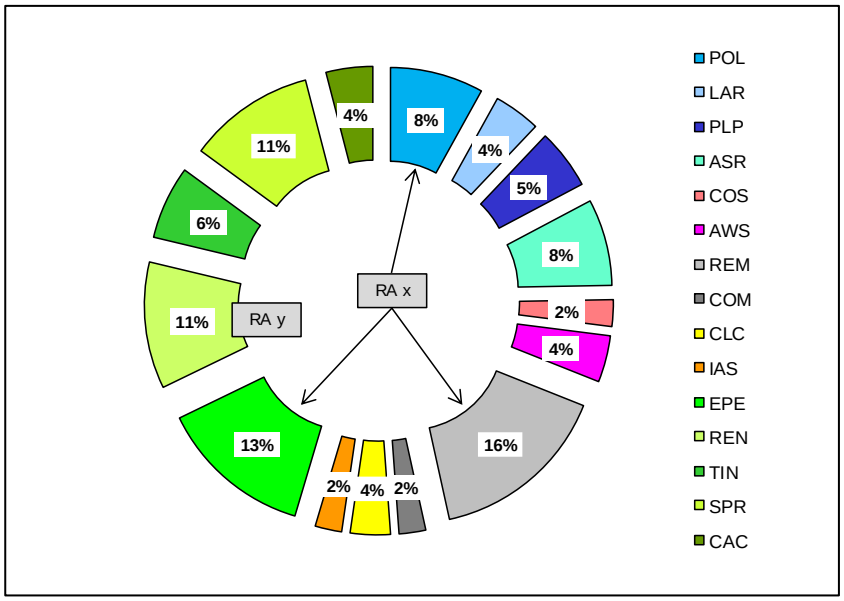


Figure 21. Occurrence of each theme among all research actions

The least important themes in terms of occurrence (2%) are “Awareness of TI stakeholders” (AWS), “Compensation measures” (COM), and “Response to spread of invasive species” (IAS). This quantitative indication must not be interpreted as a hierarchy regarding the importance allocated to the different themes but as an indicator of the level of questioning today relative to these aspects. As an example, theme IAS, as well as “Response to effects of climate change” (CLI = 4%), deal with well-known important issues for biodiversity conservation. Their occurrence is low simply because in the field of transport ecology both problematics are clearly understood, as is the set of questions necessary to treat them.

We can also see that the 4 themes linked to improving the general transport infrastructure development process (blue shade) together account for 25% of all themes. This shows that the implementation of this process is still generating many questions. We can see too that the 5 themes linked to solving the specific questions posed by transport infrastructures to biodiversity (green shade) together account for 45% of the total. This shows that the SRA is essentially dedicated to questions specific to the ecology of transport, at the intersection between the fields of ecology and transport research.

3.2.5. Great stakes of the call

All the research action of the strategic research agenda concern biodiversity (Figure 22), but they also concern other great stakes of the original call to which BISON addressed. They also concern technology (29%) and digitalisation (4%). Together they account 33% of the research actions, i.e. the same ratio as the number of research actions relevant for assessment through the TRL reference system (cf. Section 3.4, N = 31). They address social changes (15%), climate change (4%) and changing demand (3%).

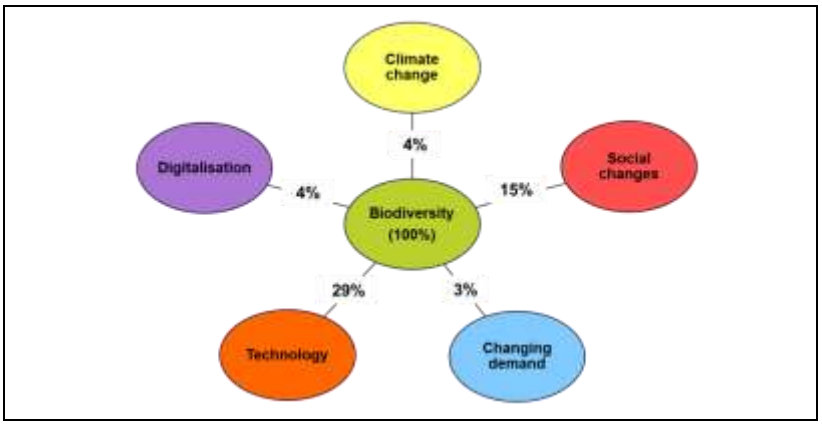


Figure 22. Great stakes of the original call within research actions (%)

3.2.6. Maturity level of RAs assessed through TRL and SRL reference systems

An overview of the different levels of maturity of all the RAs according to the TRL and SRL reference systems (cf. § 2.3.4) is provided hereafter. Research actions can present either technological or societal aspects, or both. The share of the different Technology Readiness Levels is presented in Figure 23. The TRL reference system is relevant with a total of 35 RAs (existence of a technical dimension in the RA). The majority of these (n = 23) belongs to the Research (red shades) and Development (yellow shades) phases (TRL ≤ 6). There 8 remaining RAs (green shades), which TRL correspond to the Deployment phase are however kept in the research agenda because they also present Societal Readiness Levels of the R&D phases (Figure 24). The SRL reference system is relevant for 88 RAs, with the great majority in the Research phase (n = 75, red shades), and 13 in the Development phase (yellow shades).

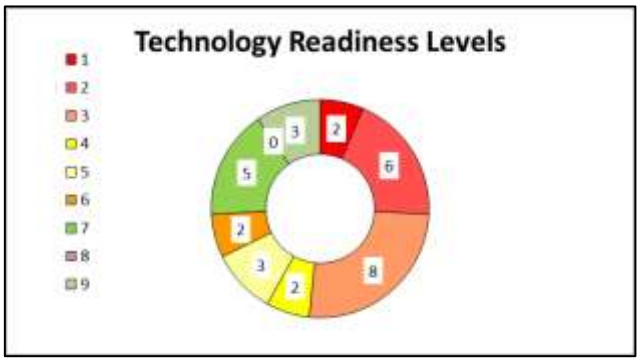


Figure 23. TRL occurrence among RAs

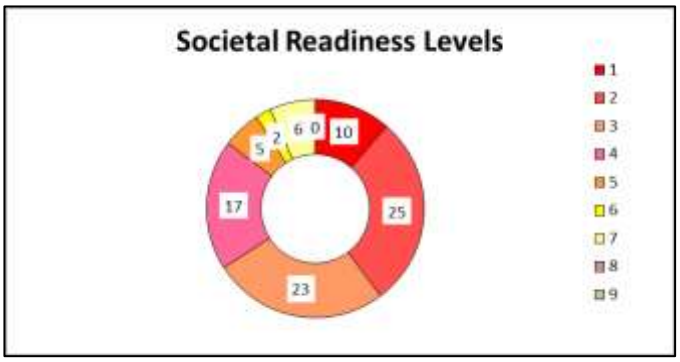


Figure 24. SRL occurrence among RAs

3.3. Tools to support R&D activities in transport ecology

3.3.1. Data collection system from the mandatory monitoring of transport infrastructures

The mandatory monitoring of transport infrastructures from their commissioning and for several years produces quantities of data which in the current state escape any possibility of exploitation for

research. Opportunities of deeper analysis, of large scale analysis, of improved feedback, of crossing with research projects are lost, to the detriment of all stakeholders.

In order to feed research on biodiversity-friendly transport infrastructures with appropriate and reliable information, the research community could set the data that should be expected from stakeholders in charge the mandatory monitoring of transport infrastructures, with their characteristics of nature, format, quality… Data produced by preliminary studies of transport project could be concerned too. Better supplied with data, transport ecology research could produce more numerous, more reliable and more transferable results for the benefit of all stakeholders. The implementation of this resource for research should also integrate the dimension of the communication system for the collection and provision of data for the research community (Figure 25).

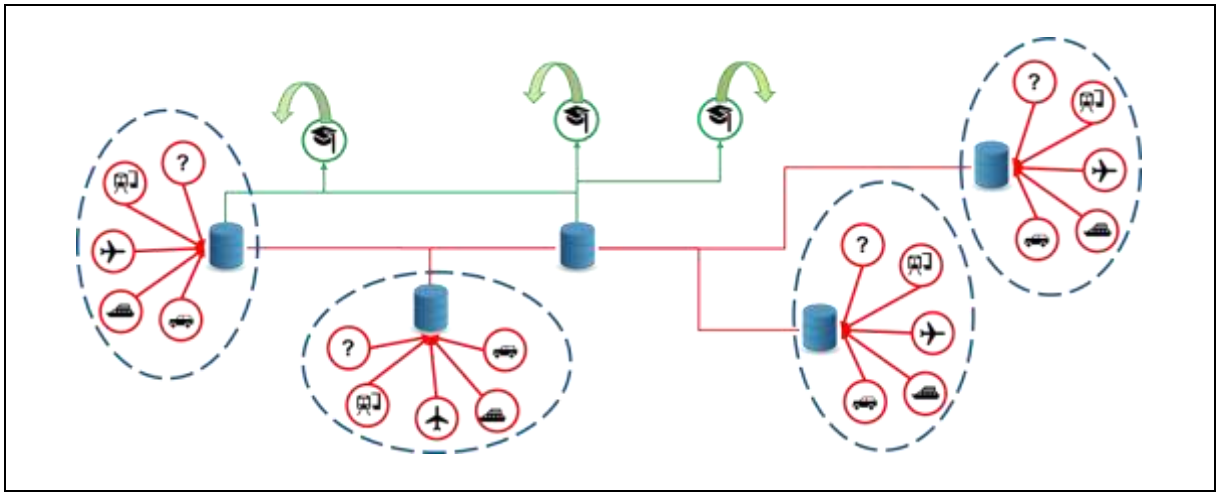


Figure 25. A system for collecting and making available for scientists the data produced by preliminary studies (?) and mandatory monitoring of existing infrastructures in all regions

3.3.2. Full-scale experimentation projects to test hypotheses and solutions

Research and development activities in transport ecology are often slowed down (or prevented for some) by the lack of possibility of testing hypotheses or new solutions on a real scale. Opportunities arise only in the context of calls for collaborative research projects involving operators (which are rare and complex to set up) or in the context of real infrastructure projects (which also offer rare opportunities of access for research and can present limitation to the share of information).

In the context of new projects but more broadly thanks to the great potential offered by the space occupied by pre-existing transport infrastructures, the possibility of proposing to operators and implementing full-scale experimentation projects should be introduced as a common tool for research in transport ecology. This would be of interest for all the fields of concern and would allow multi-disciplinary studies. For the operational side this would strengthen and accelerate the assessment of feasibility.

Figure 26. Sections of existing infrastructures can support experiments of hypotheses and solutions. Photo D. François, Université Gustave Eiffel.

3.3.3. A network of long-term study areas across Europe

A major issue of research in transport ecology is the understanding and managing of the large scale and long term effects of transports networks at landscape scale, with consideration of infrastructure types, the density of their meshing, their induced effects on anthropization… So far, with the means available for research, this problem can only be tackled by partial actions, leaving large gaps between them, making the integration and transferability of knowledge almost impossible. Developing such research implies being able to mobilize researchers from all the concerned disciplines on the same study area and for a long time (decades), to observe the same objects and actors, their evolutions and to interact together.

Figure 27. Vision of a network of diversified large-scale and long-term study areas across Europe

The great diversity of situations encountered across Europe (diversity of land use, diversity of ecoregions and diversity of transport network meshing) makes it possible to identify a set of complementary study areas on which efforts of European researchers could be concentrated. This would allow more efficient research investment, cross analysis on each areas, and cross analysis between areas. Operational learnings would benefit to all regions whatever their situation, for management and planning.

3.4. Enlighting the reference system

The process developed through the steps of WP4 brought up a fundamental question that does not specifically concern research but all types of stakeholders. It is worth being reported here as it is important in order to clarify common goals, to make all stakeholders work consistently in the same direction, to assess relevance of all decisions, field and research initiatives.

The raised requirement is to establish criteria for the definition of what biodiversity-friendly transport modes and infrastructures must be. The answer should inform transport policy and decision making at all levels (European, local, institutional, individual). It should guide R&D activities and innovation, including the application of the concept to questions not yet addressed as the features of biodiversity-friendly vehicles and practices and the way to assess their biodiversity-friendly performance. The questioning also concerns the present situation in Europe regarding the existence of high quality natural habitats (e.g. habitats of community interest) possibly located within transport infrastructure assets, then the issue of the conservation of this possible heritage.

4. ISSUES AND CHALLENGES OF THE INFRASTRUCTURE & BIODIVERSITY RESEARCH ECOSYSTEM

The relationship between transport or energy infrastructures and their environment, especially biodiversity, is an emerging topic in the institutional or research spheres. It is closely linked to the growing recognition of the impacts of networks, primarily land use change (IPBES[3]). Reflections are developing very rapidly, with a multiplicity of entries and research themes. Its structuring is currently underway both on the national and international scene with an approach that closely combines research and operational action beyond the "simple" subject of impact studies.

This theme, at the crossroads of multiple paths bringing together infrastructure operators, energy specialists, civil engineers, ecological engineers, biologists and researchers, is under strong tensions due to its cross-cutting nature and its multi/trans-disciplinarity, which make it a difficult subject to delimit. Understanding the subject as a coherent whole is still difficult and requires structured resources. Thus, the expression of research needs as well as the realisation and structuring of scientific work can only emerge in an environment that is already mature enough to formalise and express it. In the area covered by BISON, this process is currently underway not only at national or European level but also at global level. It is part of a wider process of re-examining research needs, scientific framing, on cross-cutting subjects and the tools to be mobilised to achieve them and make better use of them.

The primary objective of this deliverable is to provide a list of research topics to be undertaken immediately over a long-term period (>10 years) to integrate economic, ecological and social dynamics in a cross-cutting manner. The process of gathering these needs, developed in Section 3, has however shown that this gathering, in order to successfully consider the implementation of the proposals made, must be put into a long-term perspective and in close coordination with the research communities coming from both transport and biodiversity. The dialogue with the different deliverables produced in WP 2 (valorisation and exploitation), WP 3 (short-term needs and applied dimension) and WP 5 (financing) have allowed to refine the elements presented in this part.

Several challenges are identified and will be developed as follows:

- Structuring research funding ;
- The valorisation and exploitation of research conducted according to new paradigms.

4.1. Rethinking research, innovation and risk-taking

4.1.1. The steps of a long-term process

The analysis carried out by the BISON project teams showed that this project constituted an exception, not only in Europe but also internationally, without previous equivalent. For the first time, it was decided to engage in strategic reflection on a theme that crossed multiple transport networks and biodiversity. The call, launched in 2019, followed shortly after the first official international expression of interest on the subject published by the UN in its resolution 14/3 *Mainstreaming of biodiversity in the energy and*

[3] https://www.ipbes.net/models-drivers-biodiversity-ecosystem-change

mining, infrastructure, manufacturing and processing sectors[4] . However, this choice was not made by chance and is part of a recent and growing movement to address issues outside the usual silos in a different way. The support of the Member States for this topic through their transport ministries during the preparation of the H2020 call is, in itself, a risk-taking assumption that marks an important step, even if it has not yet been followed up in the subsequent Horizon Europe calls.

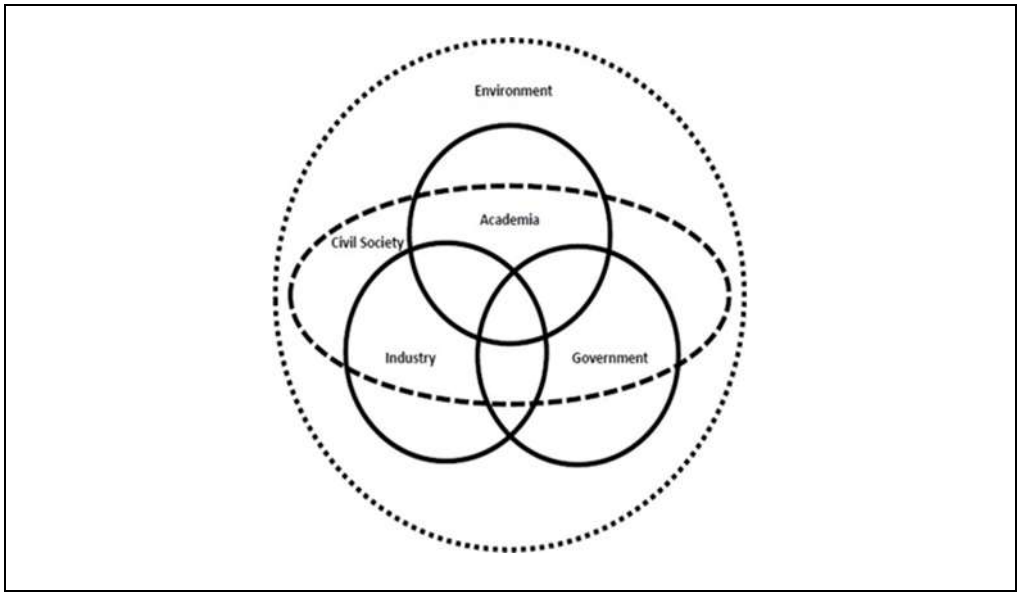


Figure 28. Interrelations between Industry, Government, Academia, civil society and Environment (Sce Wikimedia commons)

This movement is part of a more global context in which the innovative dimension of research work is increasingly declining (Park et al., 2023). This lack of visibility of research is even greater when cross-cutting issues are addressed. Yet environmental issues are, by their very nature, cross-cutting and require the development of a holistic approach, at the convergence of disciplines and users (cf. Figure 31). This same segmentation affects infrastructure research, where issues are often dealt with in a compartmentalised manner according to the type of network. The challenge of supporting a biodiversity/infrastructure transversal approach thus implies creating bridges between practitioners of the different types of infrastructures and between research communities, which must not be treated, within the framework of this analysis, as homogeneous and unitary groups.

Three challenges therefore overlap:

- to structure the development of transport infrastructure stakeholders according to a sustainability and resilience logic that integrates biodiversity and climate in the same way;
- integrate direct operations and value chains;
- develop a dynamic vision to adapt actions to the rapidly changing environmental situation in the light of IPCC and IPBES publications.

In the face of these segmentations, and at a time when expectations are high both to support the development of transport and to halt the very rapid decline in biodiversity, support for research on

[4] https://www.cbd.int/doc/decisions/cop-14/cop-14-dec-03-en.pdf

'societal challenges' may tend to favour 'what we already know'. As a result, funding agencies face additional challenges, especially when it comes to sustainable development goals, which require transdisciplinary research combining the perspectives of different disciplines and stakeholders, in a process that is inherently high-risk but offers hopes for truly disruptive change (OECD 2021). Such research has particular requirements in terms of funding and support that overlap with and go beyond those required for other types of research with a proven potential for failure but also for imperfectly controlled innovations (see below and OECD, 2020a).

This crossing of tensions is the result of various simultaneous movements induced by finalised research which can be defined as follows: "*The contents of the projects do not derive from disciplinary approaches, but from field issues which, on the contrary, call for insights from different disciplines*" (Dufour et al., 2017).

Chevassus-au-Louis (2014) reminds us that "what is *required of these targeted research operators is to be able to identify and build relevant research, in conjunction with a whole series of partners, in a context of limited resources...*". On the other hand, Hubert (2009) insists on the fact that "*the needs are often constructed by the sponsor who functions as the spokesperson for the beneficiaries with all the distortions of demand that this can engender. [...] the needs of these beneficiaries are not those of the intermediary institutions with which [...] the research teams collaborate...*". There is therefore constant pressure on the knowledge production chain and its exploitation.

Between the two, in a highly inertial process, the hope is often held that knowledge will 'percolate' on its own without always being certain, without having the certainty that it will be used or knowing who is really responsible for it (Maxim, 2022).

4.1.2. The challenges of risk-taking on cross-silo issues

The uncertain aspect of the work undertaken on the BISON theme makes it, in essence, a subject of tension, turmoil and opposition, reflecting the stochastic, dynamic and polymorphic aspect of biodiversity, in direct opposition to the desire for standardisation in the transport engineering world. The pitfalls on the subject addressed by BISON are very important and recurrent in the various partner countries:

- difficulty in problematising research needs,
- Inadequate research timeframes,
- systems of evaluation of research work outside homogeneous disciplinary fields lacking coherence with the ambitions,
- weakness of intermediary actors between research and the operational world.

However, this is not the only issue and the OECD has demonstrated this in its report *Effective policies to foster high-risk/high-reward research* (OECD, 2021).

The current system shows real signs of weakness when it comes to tackling *'out of the box*' interdisciplinary subjects (or requiring a long time beyond the three years of classic research). This leads to a paradox: the general desire is to ensure that the projects supported will necessarily bring innovations and improvements. However, only projects whose results are known at the time of

submission are supported (or almost so). Risk-taking is minimal, investments are conservative (OECD, 2021) and conceptual breakthroughs are almost invisible because the evaluators themselves find it difficult to appropriate projects of a cross-cutting nature. The system must therefore be adapted to allow the reintegration of a risk-taking dimension by mobilising the research chain: call design, project development, evaluation and valorisation/exploitation of results.

It is therefore necessary to reflect on the performance indicators of projects that are essentially based on technical and economic objectives of the TRL type that take little or no account of results that cannot be economically valued.

There are only a few initiatives that support a deliberately riskier approach, but they often too focus on technical subjects with a limited systemic scope. The desire for a quick return on investment (RoI) also reduces the capacity to reach a critical mass of knowledge. It is necessary to develop the possibility of a medium or long-term RoI to support market positioning, regulatory alignment and attractiveness to investors. The focus on technical models and solutions neglects the social and political dimensions which, in themselves, constitute critical and necessary innovations, as was demonstrated by the discussions of industrial actors during the workshops held during the BISON project.

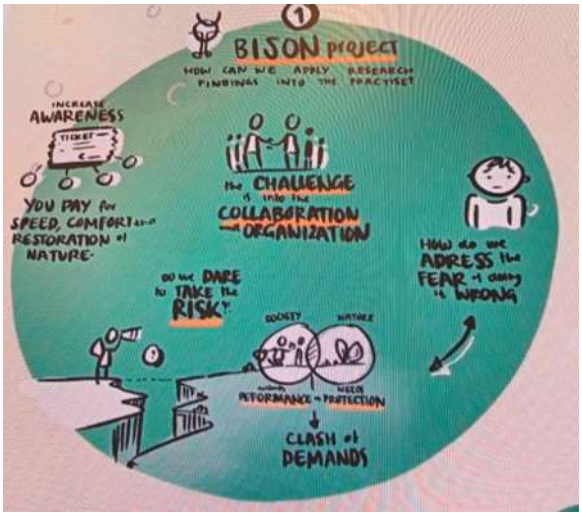


Figure 29. UIC BISON Workshop, Sustainable Infra Week (2023.02.27)

Transformative Research" is defined by The US National Science Board as research that "*involves ideas, discoveries, or tools that radically change our understanding of an important existing scientific or engineering concept or educational practice or leads to the creation of a new paradigm or field of science, engineering, or education. Such research challenges current understanding or provides pathways to new frontiers*. (National Science Board, 2007). Risk-taking is implicit in such an approach, as research aimed at radical change carries a greater risk of failure than incremental research, but it also generates potential opposition from stakeholders who may prefer to go with the flow. There is a real and deep aversion to risk and a very low willingness to take the risk of failure which can also be a success leading to truly transformative change. Thus transformative research is not only interdisciplinary (although this is more often the case), it is above all integrated into an ecosystem where it can be tested and operationalised throughout the sector's value chain. On BISON's themes, this ecosystem is still in the making, even if it is evolving rapidly and globally, as shown by the initiative

of the UN Environment Department, which is developing a global knowledge community with the Sustainable Infrastructure Partnership[5].

To get past this duality, the OECD's definition of research at risk (see rationale box below) seems to us to be particularly well suited to the themes developed by BISON and directly echoes the "Transformative Changes" proposed by IPBES by accepting an interconnection of simultaneous or parallel initiatives, a non-linear process marked by advances and setbacks, unexpected effects, all within a framework open to serendipity (OECD, 2009).

High-risk, high-reward (HRHR) research is research that (OECD, 2021):
1) strives to understand or support solutions to ambitious scientific, technological, or societal challenges;
2) strives to cross scientific, technological, or societal paradigms in a revolutionary way;
3) involves a high degree of novelty;
4) carries a high risk of not realizing its full ambition as well as the potential for high, transformational impact on a scientific, technological, or societal challenge.

4.1.3. Ways to support greater risk-taking

Supporting the ambition of the themes carried by BISON must mobilise important developments in terms of research, including:

- **Develop a dynamic long-term vision (>10 years)** for both funding and expectations by supporting researchers in this process through an overhaul of their evaluation system (OECD, 2021; CoARA, 2022);
- Supporting **new approaches to impact and dependency assessment** with the wider research community (CoARA, 2022[6]);
- **Framing risk-taking through a rigorous process of scientific excellence** that allows proposals to be objectified by capitalising as much as possible on the knowledge already developed to reduce the continuation of ineffective practices while optimising the funding available (Santangeli & Sutherland, 2017[7]; Sutherland, 2022).
- **Supporting the research ecosystem with third-party actors who** can act as a link between funders/users and researchers: **knowledge brokers** (Sutherland, 2022) whose main actions would be:
  - To facilitate the interpretation of data for decision-making by assessing the strength of information from different sources as well as local conditions;
  - Produce accessible information that incorporates evidence;
  - To assist in the design of tests to assess effectiveness.
- **Strengthen the development of indicators** based on the Global Biodiversity Framework and sharing data via international databases (e.g. GLOBIO).

[5] https://www.greengrowthknowledge.org/initiatives/sustainable-infrastructure-partnership
[6] Ten commitments to establish a common direction for research assessment reform, while respecting organisations' autonomy.
[7] Santangeli & Sutherland (2017) calculated that "*a programme solely carrying out the effective measures would save about €78,854 (or 21.9% of the budget) annually. They then calculated the gain from this research: given the initial investment of about €156,211 for a PhD thesis, the financial return over a 10-year period ranges between 292% and 326%, depending on how costs are estimated. This shows that research on the effectiveness of actions can be hugely cost effective*.

Far from renouncing scientific excellence, risk-taking, whether financial, boundary and/or inter/trans-disciplinary, affirms the strength of trials in seeking evidence, reviewing hypotheses, adjusting, applying or demonstrating. In the area of BISON's topics, the use of systematic reviews, methods from the medical field to process thousands of publications to develop meta-analyses, has allowed the identification of areas for improvement of work (Sordello et al., 2017). The transfer of "*knowledge produced [...] which is supposed to be "transferable" to non-scientists*" (Albaladejo et al., 2009) therefore requires the development of tools and intermediary actors such as "knowledge brokers", with two major changes to be made:

Feedback from the Cohnecs IT systematic review on the ITTECOP National research programme (France)

The work carried out within the framework of the Cohnecs-IT project showed how the vast majority of research work and publications on this subject at the crossroads of infrastructure and biodiversity had methodological weaknesses that did not allow them to be qualified as robust. Since this realisation, each new project undertaken on these subjects mobilises both a quality process based on a detailed data management plan and close support from scientific and operational referents.

- Professionalise these intermediary actors between researchers and operational actors in order to make the processes more fluid, whether they are public or private.
- optimise knowledge by developing tools to better master the immense mass of accumulated knowledge already available and thus better target what needs to be financed to fill any gaps (such as systematic reviews as explained above).

However, the question of their long-term financing and their capacity, if necessary, to pursue a risky approach outside the usual standards without losing access to funding will be raised.

Jean-Claude Gardin, (Albaladejo et al., 2009) insists on an essential point of the challenge facing researchers and users of research: "*the abundance of scientific production no longer allows even specialists to read all the work carried out on an issue*", not to mention time, an incompressible resource. The diversity of the knowledge mobilised and the multiplicity of the targets targeted make the role of the media all the more difficult, but indispensable.

This transversality implies being able to develop applied research outside the traditional silos due to a complete holistic approach that can involve the co-construction of knowledge through industry-research collaboration. This also makes the transfer of research to operational implementation more complex, while avoiding as far as possible the production of catalogues of case studies whose added value is low because of their reduced reproducibility[8] . The optimisation of the knowledge acquired requires, in the context of infrastructures, the realisation of its deployment potential on other networks than those for which it was initially carried out and for which the results presented in Section 3 have shown the very high rate of possible convergence (from 75 to 98%). This result highlights the importance of working on the criteria to be integrated: additionality, replicability.... However, as analysed in deliverable 5.6, inter-infrastructure research remains very weak.

[8] Sutherland, 2022: "*case studies tend to be weak at providing evidence for the effectiveness of actions, as they lack controls or replication, and often include multiple actions carried out simultaneously or adapted over time. This means that effects cannot be clearly disentangled, and it is likely to be difficult to extrapolate results to other contexts."*

In order to provide the subject with real resources, a key issue is to identify the means and resources available to the research players in order to optimise the resources of each (Grout & Autret, 2021[9]). This last point is all the more obvious for BISON as the analysis of the RIPs/RAs in the other parts of this deliverable has shown a very high potential for synergy of research questions between infrastructures on the subject of biodiversity (between 75 and 98%), which is very far from the approaches currently undertaken in the framework of Horizon Europe calls (box A).

Box A : Cross analysis of key words in work program of cluster 5 and 6 - 2023-2024 call : a clear and net lack of transversal approach

	Biodiversity	Climate	Energy	Environment	Infrastructure	Innovation	Research	Transport
Cluster 5	61	1115	1748	473	230	530	501	597

	Biodiversity	Climate	Energy	Environment	Infrastructure	Innovation	Research	Transport
Cluster 6	785	990	173	1462	119	765	880	14

Cluster 5 (Climate, Energy and Mobility)**:** 190 topics (2023/2024), no call for projects concerning biodiversity except in connection with carbon sequestration or adaptation to climate change. The term biodiversity is almost exclusive to the introduction and partnerships with China.

https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-8-climate-energy-and-mobility_horizon-2023-2024_en.pdf

Cluster 6 (Food, Bioeconomy, Natural Resources, Agriculture and Environment)**:** 176 topics (2023/2024), no mention of transport in the calls beyond the introduction. The term infrastructure refers either to green infrastructure (ecological networks) or to research infrastructure.

https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-9-food-bioeconomy-natural-resources-agriculture-and-environment_horizon-2023-2024_en.pdf

4.2. Governance and funding of research and innovation

"Given the scale of the biodiversity crisis and the limited funding available to tackle it, it can often feel that any diversion of limited resources and funds [...] is hard to justify" (Sutherland, 2022).

Biodiversity loss remains difficult to assess from a global point of view due to its complex nature and, unlike climate change which can be measured by the rise in the earth's temperature over long series, the absence of a single relevant indicator (De Saint-Martin et al., 2022), which in this case is more a question of a set of complementary indicators that are more complex to master. The will to act is present in all the countries surveyed as part of the BISON project, but the difficulty of identifying specific investments is real. This situation is also found at the global level, where under-investment in this area has been estimated at 440 billion dollars per year by the World Bank (De Saint-Martin et al., 2022), or even more. The OECD (2020b) lists $500 billion of harmful public subsidies per year on a global scale, i.e. 5 to 6 times more than the total expenditure in its favour, but this ratio is probably underestimated because the OECD's Transport Department estimates that average annual investment

[9] Analysis report on the potential for mutualisation of research in infrastructure and environment, 2021 (unpublished)

in infrastructure by 2030 will amount to more than $3,500 billion. Such a discrepancy illustrates the difficulty of identifying the issues.

As summarised by the OECD in its Biodiversity Finance Report (OECD, 2014)*: "the benefits that accrue from biodiversity are not fully reflected in market prices: their value is underestimated and the supply of biodiversity public goods is insufficient. Private decision-makers do not always take into account the costs and benefits to society of conserving and sustainably using species and natural resources, and are generally only concerned with the private costs to them. As a result, biodiversity remains undervalued and continues to be impoverished."* The reason for this lack of consideration also stems from the fact that private decision-makers have a mantra of privatising the benefits and externalising the social and environmental costs to public actors and associations, even if this point tends to evolve.

In fact, funding for biodiversity remains structurally insufficient, whether for protection, conservation or, even more so, for research. For example, at the global level, the additional costs of achieving the twenty Aïchi objectives over the 2010-2020 period are estimated at between $150 and $440 billion per year, a figure that was re-evaluated at more than $700 billion after the COP15[10] . **In this context, the intervention of public actors remains the most decisive and reliable tool for biodiversity action**. Private funding for biodiversity remains limited. However, it is surprising to note that the public authorities, the main investors in research, are almost absent as targets of the work. It is as if, in a way, the administration had a tendency to forget itself and was only an "administrative vehicle" with an incomplete vision of its own needs but also of its own resources.

HRHR research funding mechanisms (OECD, 2021)
Four main funding categories can be identified:

- Funding mechanisms **specifically designed** to support HRHR research and that are supporting such research as a primary goal;
- Funding mechanisms that have **HRHR research as their primary mission within a broader set of objectives;**
- Funding mechanisms in which supporting **HRHR research is a secondary goal** or an important consideration in the proposal evaluation process;
- Funding mechanisms geared toward **supporting scientific research with multiple possible goals** including advancing scientific knowledge, achieving economic outcomes, or advancing societal

Public operators sharing risks with the private sector have developed significant financing systems for the climate transition, but little for biodiversity. While experience with climate change can be a resource for developing biodiversity indicators, the subject is marked by an enormous difficulty in understanding the financial volumes related to biodiversity, including in countries that have adopted the use of a "green budget" such as France, Austria or Greece. As a result, it is difficult to clearly formalise objectives or means in a strategy, whether it be research, institutional or industrial. These features are common to almost all of the players interviewed and are in line with the OECD's analysis, for which the funding of such 'out of the box' subjects is most often a secondary objective (OECD, 2021).

Without having similar figures for the different countries, the analysis carried out by the Inspection des Finances in France shows that the main items of State expenditure on biodiversity policies concern the acquisition of knowledge (26.7% out of a total of approximately €4 billion) and the financing of protected areas (21.8%). These elements also came up regularly during the exchanges. The

[10] https://www.banquemondiale.org/fr/news/immersive-story/2022/12/07/securing-our-future-through-biodiversity

investments made are concentrated in two main categories linked to the application of the mitigation hierarchy: the remediation of existing effects or the reduction of future damage.

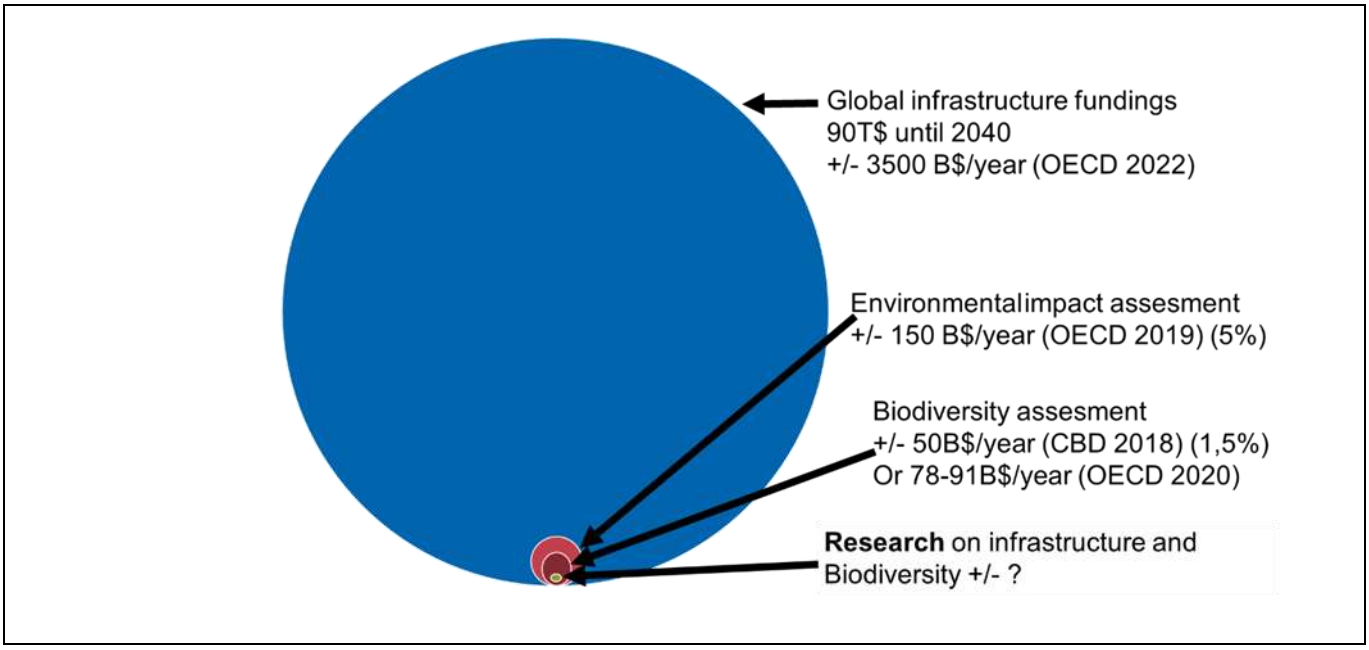


Figure 30. Potential international ratio of infrastructure and biodiversity investments

Although the organisation of funding for research, innovation and application (RID) on the theme of infrastructure and biodiversity is fairly similar between the different European countries, the subject remains marginal and fragmented. The amounts dedicated to RDI remain very difficult to assess because they are often mixed with broader environmental actions that do not allow their precise nature to be targeted and fall into categories 3 (secondary goal) or 4 (multiple possible goals) established by the OECD (see Section 4.1.2). In this very complex framework, dialogue and the pooling of knowledge between the different types of infrastructure is still very incomplete, even if this point is not exclusive to the present theme.

4.2.1. Unbalanced, fragmented and insufficient funding for RID

The difficulty in mobilising funds for RID is due to a combination of factors:

- The **necessary interdisciplinarity of the subject**, which is **primarily carried out by a few intermediary actors in the public sector, means that the research sector is only slightly interested or dispersed** and that it is very difficult to assess the volume of funds actually invested (see Figure 31 - Research and innovation on transport and biodiversity - schematic organisation of the disequilibrium)
- **The mobilisation of private actors is difficult and heterogeneous.** Private research centres are rare and concentrate on more downstream subjects. Several factors make it difficult to effectively integrate biodiversity into private economic choices:
    - As a common good, biodiversity generates collective benefits that cannot be captured by private actors, unless a market price is assigned to them;

- assigning a price or monetary value to biodiversity is theoretically difficult and of limited interest because of the multiplicity of data and indicators to be taken into account and the diversity of possible value scales;
- the practical implementation of the measurement of benefits, risks and impacts around biodiversity remains incomplete and complex, in particular because of the multiplicity of ecosystems and their interactions;
- Once measured and possibly monetised, the benefits of biodiversity conservation are felt over the medium and long term, which makes them difficult to integrate into investment choices with different timeframes.

➢ **The applicative and operational dimension** is the primary objective sought, with a focus on certain infrastructures or local territories and less on a more global approach, which also reduces the base of researchers capable of responding to expectations and needs. This point directs the available investments more towards particular case studies or follow-up observations than towards research that allows for a more general approach, beyond the obvious.

➢ **The fear of instrumentalisation (greenwashing) on the** one hand or of blocking on the other can also help to shed light on the difficulties encountered.

➢ It is also difficult to integrate the **"fluctuating and dynamic" aspects of biodiversity (stochasticity) into transport or energy policies**, as opposed to climate issues, with which they are often mixed under the terms of environment or nature, which does not help to establish a consolidated vision of the issues.

The limited national use of European funds, which may offer an interesting avenue for financing, is often affected by administrative red tape, not to mention the fact that these funds also suffer from a segmented approach (see details in Autret et al., 2023 – D5.6).

The research and innovation ecosystem is unbalanced by a clear predominance of operational actions (Figure 31). Innovation or applied research work, with a fairly high TRL level, is favoured, especially in the 'project' stages of the infrastructure life cycle. Upstream research or research of a strategic nature is very rare, often isolated, and makes it difficult to gain perspective on the entire process at the territorial level. Much more weight is given to the financing of technical solutions to the detriment of socio-economic or socio-political approaches, resulting in a loss of global vision of objectives in favour of a specific use. The SHS offer a major lever for research on the theme of BISON.

But this increase in value refers directly to economic performance indicators for research. The process of technical maturity of research is illustrated by the diagrams defining the TRL (Technology Readiness Level – Table 2) or even the BRL (Business Readiness Level). TRL/BRL type tools were developed essentially for the industrial sector, in a rather linear process and tend, in the vast majority of cases, towards economic valorisation which becomes a central objective in the display of success.

However, this objective must be questioned in relation to what cannot be directly measured by this indicator, such as biodiversity, and which is part of a common good. However, this iteration is difficult to transpose to interdisciplinary environmental issues, with various spatio-temporal scales to take into account. This difficulty echoes the work of Olivier Bommelaer (Bredif & Simon, 2021) for whom '*the absence of monetary quantification is [...] assimilated to an absence of value for society*'. This is primarily aimed at environmental research and research on biodiversity in particular.

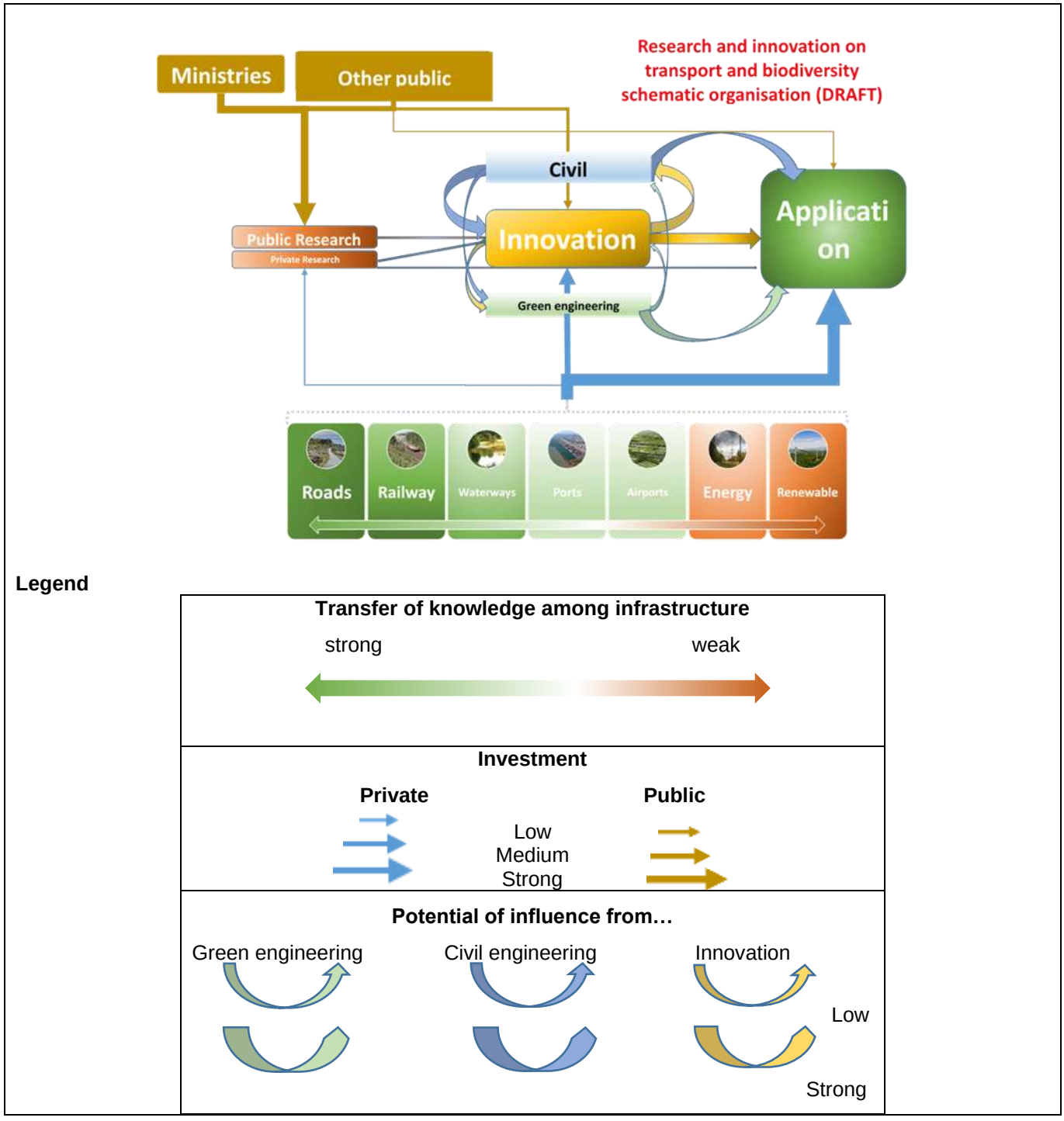


Figure 31. Research and innovation on transport and biodiversity - schematic organisation of the disequilibrium

Moreover, the targets are almost exclusively identified as private companies. It is in fact very surprising to note that the public authorities, the main investors in research (Figure 31), are almost absent as targets of these development tools. It is as if, in a way, the administration had a tendency to forget itself and was only an "administrative vehicle" with a lack of vision of its own needs and resources

But is it possible to limit the exploitation of research to its economic effects? How can we take into account the legal, societal or environmental maturity of a research topic? These questions, which are a source of regular tension, result from a confusion between exploitation, appropriation and commercialisation. These tensions can also result from a difficulty in the strategic management of research, which can also be integrated into an administrative process that may favour form over substance and the immediate over the longer term.

From an operational point of view, the weakness of research into infrastructures and biodiversity has several consequences, marked in particular by the weakness of the industrial sector capable of meeting the needs and its almost fractal fragmentation in the various Member States. The economic models that would support the strengthening of a structured sector are also weak. **This weakness is reinforced by insufficiently demanding specifications or public procurement, which do not encourage the introduction of more innovations**. Preference is therefore given to tried and tested processes and tools that are either old, not having been updated with the latest scientific findings, or implemented in a manner that is too fragmentary to have a real effect. Collations of good practices developed empirically over decades are therefore favoured over possible meta-analyses.

4.2.2. The challenges of the valorisation and exploitation of research

Despite the major sums invested, the transfer of research to fuel reflection and guide decision-making does not offer the hoped-for results, especially in terms of environmental issues and biodiversity in particular. The multiplication of investments and technological promises show their limits in the face of the need to develop a holistic approach that touches on the complexity of action systems and has to deal with dynamic processes that challenge a rise in generality.

The initiatives undertaken at national, regional or international level show an awareness of the importance of appropriating the knowledge validated by research in order to develop effective action. This requires a voluntary change of approach to integrate and create a symbiosis between natural and man-made ecosystems in the sense of "living together". To this end, the "transformative changes", recommended by the IPBES (IPBES, 2019b), must be undertaken by relying on a key resource: the development of a common heritage of scientific knowledge to support action.

- **Strengthening knowledge sharing**

The applicative and operational dimension is the primary objective, with a focus on certain local infrastructures or territories and less on a more global approach, which reduces the base of researchers capable of responding to expectations and needs. This point directs the available investments more towards particular case studies or follow-up observations than towards research[11] . This increases the formal volume of research but at the same time dilutes its quality, as demonstrated in the article by Park et al. (2023) and confirmed by the interviews conducted as part of Deliverable 5.6 of the BISON project.

For several decades now, the research support system has been organised around disciplinary fields mobilising well-established operational exploitation processes (industrial or institutional) with a growing

[11] 27% of the French budget dedicated to biodiversity is dedicated to knowledge feedback (De Saint-Martin et al., 2022) https://www.igedd.developpement-durable.gouv.fr/IMG/pdf/014389-01_rapport-publie_cle512226.pdf

number of players and resources at national, European and international level, which identify exploitation in an economic process as "[placing] itself *at the interface between research and operators. It is carried out by a group of professionals who understand the issues at stake for researchers on the one hand and for companies on the other" (Réseau C.U.R.I.E., 2021)*.

Figure 32. The valorisation process of public research (from Réseau C.U.R.I.E., 2021).

However, valuation very rarely generates net financial profits, and even less so in the short or medium term, which means that it must be conceived in a dynamic manner, over time, with a more strategic approach (Lallemant, 2013) integrating direct societal and environmental issues (Figure 32). Latour (2001) analyses this difficulty in truly setting the framework, and in keeping it, through the prism of science in action. He thus directly raises the question of the valorisation of research from the point of view of researchers and identifies the difficulties encountered, which were also recognised by the Cour des Comptes (2018). Indeed, the process is significantly different, often undervalued in their evaluation process. These tensions, identified by Lallement (2013) and Morant (2021) run through all countries

To explain these challenges, the CNRS's Institute of Ecology and Environment (RPT INNOVAE, 2022) identifies three obstacles to the exploitation of environmental research which directly echo the subject dealt with by BISON:

1. Visibility of innovation potential ;
2. The small number of actors ;
3. The lack of interaction between research units and non-academic actors, a phenomenon increased by their dispersion.
4. A fourth obstacle that we would add is the fundamental lack of capitalisation of knowledge developed in the environmental research or operational field. The almost fractal dispersion of actors makes it difficult to advance operational action and does not allow for the development of a sustainable ecosystem in this field of knowledge, which the work undertaken in the framework of

the European BISON project[12] has very clearly analysed. Each local, European or international player seeks to initiate its own actions, without effectively considering possible synergies with actions carried out in other countries or within the same country. The potential is real, but the actors need to be brought together. However, what is not integrated into the body of knowledge cannot be measured and is difficult to include in the decision-making process.

Whether at local, national, regional or international level, it has become essential to mobilise the knowledge already developed in order to progress by developing a real leverage effect. As a direct consequence of this difficulty in capitalising on knowledge, Horizon Europe's clusters are not easily open to cross-cutting initiatives, despite their willingness to work outside of silos. However, this situation could change significantly from 2024 onwards with the obligation for companies to produce extra-financial reports that include biodiversity: the CSRD (Corporate Sustainability Reporting Directive[13]).

- **The development of intermediary actors: knowledge brokers**

Resolving these tensions requires an intermediary actors able to organise the link between the parties and ensuring the animation of knowledge resulting from research so that operational actors appropriate it, but also, at the same time, that the evolution of research communities capable of better understanding the needs of research sponsors is supported. The Cour des Comptes is fully aware that it is necessary to have "*alternative solutions* [which] should *favour more modest promotion mechanisms, whose financial resources would be adjusted to the ambitions [...] which would make it possible to encourage greater appropriation of the theme of promotion*" (Cour des Comptes, 2018). These solutions should not be exclusively technical but should have two complementary components which seem essential:

1. Time to mature the ownership processes;
2. Develop trust and mutual knowledge between research actors and end users.

However, these two points are not very closely associated with the performance indicators for the promotion of research, which take many forms. They require continuous proactive scientific leadership to complement the research teams and sponsors, a point emphasised by Albaladejo et al. (2009): "*The transferability of knowledge for the treatment of environmental issues is posed [...] from the outset between researchers from the different disciplinary fields involved. But the resolution of environmental problems is often subject to management and a set of actions rarely implemented directly by the scientists themselves"*.

In this respect, the CoARA initiative supported by DG Research has great potential to help, at least in part, to resolve the difficulties encountered and to develop renewed interdisciplinary research evaluated according to different criteria that will enable human, time and financial resources to be optimised.

4.2.3. Prospects for development

[12] BISON, Biodiversity and infrastructure synergies and opportunities for European transport networks, H2020 - grant agreement No 101006661 https://bison-transport.eu/

[13] https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

There have been several recent shifts. All of the above points must be qualified by other factors that are more positive in appearance

Mobilising private funding on the scale needed requires greater knowledge of the risks and effects of economic activities on biodiversity. The specific characteristics of biodiversity make direct private financing of biodiversity unlikely in the short or medium term. Biodiversity is a common good that is difficult to value. Despite their positive externalities, preservation or restoration actions are very rarely profitable for private actors. Only a very limited number of projects, most often related to the climate transition and carbon offsetting (nature-based solutions), are currently the subject of private financing that is theoretically beneficial to biodiversity but which remains in its infancy and concentrated on developing economies.

However, there is a growing affirmation by private stakeholders to develop the RID sector to support the development of CSR obligations to take into account the effects of developments on biodiversity [To be completed by CDC Biodiversity + UIC]. It is indeed necessary for both private and public actors to have performance indicators that integrate biodiversity into the management of strategies, the evaluation of risks related to the consideration of these issues and, in the long term, to allow their integration into the investment decisions of private actors in projects that are less harmful to biodiversity (De Saint-Martin et al., 2022).

A re-examination of knowledge needs further upstream in the life cycle of infrastructures shows a desire to anticipate difficulties linked to artificialisation (prevention rather than cure); at present, a few specialised public bodies such as CEREMA in France, Expertennetzwerk with BAST in Germany or TRAGSA in Spain are playing this growing role of supporting knowledge. But if countries of this importance manage to reach a "critical mass", this remains difficult to achieve elsewhere.

The various post-Covid recovery plans (EU-Green Deal) have also had a clear impact by directing the "greening" of funds, accentuating the convergence of national, European and international objectives. These actions have had an important effect by requiring the active convergence of funds on cross-cutting policies, even though situations may vary from one country to another. The temporal dimension of long-term investment strategies is also developing with a growing desire to prevent and anticipate as much as possible. The coordinated and optimised use of the various European funds can, in this respect, constitute a real opportunity. However, here too the funds focus on operational aspects and little or no attention is paid to research and the role it could play in a more strategic approach that could optimise the strengths and resources available. Finally, scaling up can also be a challenge even for a structured community with years of experience, as shown by the experience of Alternet and Eklipse in finding a financial balance independently of the funds that supported them during their maturation phase.

The joint analysis of the European funding, the interviews and the discussions held during the workshop of 31 January in the framework of WP5 (deliverable D5.6) make it possible to propose several possible avenues for development. During the drafting of this deliverable, it appeared important to underline that what exists at both national and European level today offers a strong potential to better support the subject.

The main pitfalls identified in terms of research and innovation funding are

- Fragmentation of R&I actors and funding;

- Difficulty in carrying out a multi-silo approach;
- Delayed investment in the operational phases;
- Under-mobilisation of private actors in the face of a subject with an uncertain economic model;
- Few actors are able to develop a cross-cutting approach;
- Inertia of traditional research systems not supporting risk-taking.

Faced with these challenges, the proposals below are based on a positive dynamic of increasing scope, marked by a simultaneous series of initiatives at various national, European and international levels. The will of the stakeholders is asserting itself. The proposed solutions are therefore based on several common factors:

- Optimisation of existing (potentially co-constructed) tools to increase overall coherence;
- Taking into account a long time frame of results in the framework of a common good approach and non-financial benefits;
- An acceptance to support riskier initiatives with greater potential;
- An improvement in the capitalisation and valorisation of the work undertaken to support an evidence-based approach.

We propose three complementary levels of intervention marked by deep interactions with the global potential for action in this field

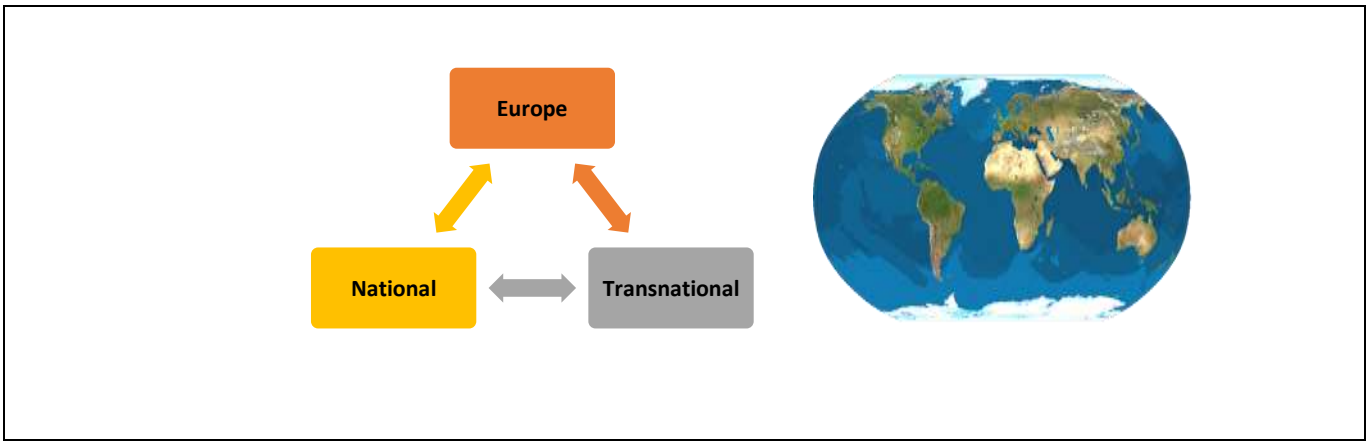


Figure 33. The sharing process of knowledge between different levels of actors

- **At European level**

Europe has developed highly specialised funding to meet the specific needs of the various specialities. However, as shown in D5.6 (Autret et al., 2023), it is almost impossible to identify the funding that specifically targets infrastructure and biodiversity. To overcome this problem of the growing scale of the treatment of cross-cutting issues, it has become necessary in recent years to develop different approaches to cross-cutting issues, such as the CoARA initiative (Coalition for Advancing Research

Assessment[14]). These tools correspond to a need for coherence in the face of complex issues that cannot be dealt with through the usual channels.

We propose two possible paths:

1- The **strengthening of partnerships through the creation of a transversal work space** that ensures the coherence of issues and is capable of supporting cross-cutting subjects, even when their "profitability" is not assured;

2- This role could also be played at the level of the "**Missions**" by ensuring the coherence of multiple subjects and funding: research, innovation, operational;

For these two developments or adaptations of pre-existing frameworks, one of the major challenges will be the ability to maintain a sufficiently low administrative complexity and a sufficiently high openness to risk (OECD, 2021).

From an organisational point of view, such an evolution will have to integrate the identification of transversal experts capable of appreciating the particular added value of the hybridisation of knowledge.

3- A third development could also be in the **capitalisation of funded knowledge**. During the interviews, in addition to the fact that the projects dealing with infrastructure and biodiversity were spread over a multitude of different offices, it appeared that the results of many projects were not or no longer accessible a few years after their end, resulting in a loss of sometimes major knowledge. It is indeed crucial to be able to capitalise on what has been learnt in order to ensure that knowledge centres are able to increase the level of generality. A process along these lines has been initiated by the European Environment Agency, but it is still in progress.

● At national level

National resources are highly fragmented and can be strengthened at two levels

- **Support the role of resource centres or centres of expertise and their networking.** Centres such as CEREMA in France, BAST in Germany with the Expertennetzwerk, TRAGSA in Spain or their equivalents in the various countries are very specific spaces, which have to integrate multiple public policies in order to achieve their missions. In this context, they must develop a "**knowledge broker"** role (Sutherland et al., 2022) that is essential to support essential cross-sectoral research or innovations on the subject of infrastructures and biodiversity. Finally, they occupy a special place between public and private stakeholders because of their ability to better analyse needs that are not necessarily clearly formalised. This also allows them to be key players in transition actions.

The centres of expertise can also play a key role in ensuring the coherence of national strategic plans, which are still struggling at this stage to fully interact.

- **Support the creation or strengthening of research foundations to increase the mobilisation of private actors.** Research foundations such as the FRB have become key

[14] https://coara.eu/ - 493 members as of 16 March 2023

players to better accompany private companies and better coordinate private funds. The actions carried out in Italy show how effectively they can complement the actions carried out by the public sector. They provide the operational flexibility necessary for the coordination of private actors who are not necessarily used to extensive cooperation. Moreover, this tool also represents a flexibility to integrate more distant actors such as investment banks (example of the Global Infrastructure Basel association[15] or the Sustainable Infrastructure Foundation[16]).

The medium/long-term stability of the funds available to guarantee the sustainability of operations must be an essential input to support risk-taking. This process, in the specific case of BISON, should, as far as possible, involve public and private actors.

- **At the trans-national or cross-industry level**

A key issue in the funding of research and innovation, however, is the transition between the national and European or even international levels.

Three circles seem to be emerging at this stage:

- **The strengthening of language-based cooperation** such as DACH (Germany, Austria, Switzerland) or Nordfou (Denmark, Sweden, Norway, Finland and Iceland), which offer a synthesis between national specificities and transnational issues, making it possible to overcome language barriers such as English, which remains a major barrier for the vast majority of professionals. Initiatives between French-speaking countries[17] or Spanish- and Portuguese-speaking countries[18] have also been identified. Such initiatives can more easily carry out joint calls for projects such as systematic reviews and exploit the results.
- **European professional or institutional networks** such as the ECPR or RECs are bodies that are very directly able to optimise their members' investments in the subject, even if at this stage their own resources remain limited. Their strength lies in their specialisation and their central role vis-à-vis the member public authorities.
- Lastly, **support for transversal research networks such as Fehrl or IENE**[19] , which were originally created in the 1990s to meet the common needs of transport ministries in terms of biodiversity management. These associations, intermediaries between the national and European or international levels, can play an increasingly central role as "knowledge brokers" (White et al, 2023). Like the centres of expertise, these networks can better coordinate public and private actors in an approach that is optimised both financially and from the point of view of knowledge production. The Sustainable Infrastructure Partnership - Community of Learners of the UN Environment Department is a major initiative in this respect for bringing together knowledge[20] .

[15] https://gib-foundation.org/
[16] https://public.sif-source.org/
[17] https://www.sifee.org/
[18] https://latinamericatransportationecology.org/?lang=sp
[19] www.iene.info
[20] https://www.greengrowthknowledge.org/initiatives/sustainable-infrastructure-partnership

5. CONCLUSIONS

Before BISON, there was no strategic research programme in the field of transport ecology, either in Europe or anywhere else in the world. Thus, drafting the BISON SRA for biodiversity-friendly transport infrastructures in Europe had to start from scratch. Strategic research agendas from neighbouring fields (transport infrastructures, biodiversity conservation) available and were consulted in order to draw inspiration in terms of form and content. Regarding the method to draw up the agenda (identification and classification of research needs), in order to allow the widest possible reflection, the approach was not only to draw on the knowledge and experience of WP4 members, of BISON members and the scientific literature, but also to open the process to collect views from various concerned stakeholders (use of a bottom-up approach). This has led to a great mass of information to be processed, with the counterpart of minimising the risk of leaving blind spots in the search for new avenues of research.

The Strategic Research Agenda sets out 92 research actions, divided into 14 major problematics. Half of the research actions (48%) can be completed in the medium term (i.e. 10 years), compared with 16% in the short term (5 years) and 36% in the longer term (23% within 15 years and 13% beyond). The 5 problematics which require the highest research effort/investment are “Disturbances experienced by species in the vicinity of transport infrastructures”, “Overall pressure to biodiversity from transport infrastructures in space and time”, “Considering landscape dynamics in transport infrastructure projects”, “Involving stakeholders of the crossed territories” and “Characterising biodiversity-friendly performance for continuous improvement”.

The analysis of themes (an indicator of the level of concern by stakeholders) shows the importance of the questions specifically posed to biodiversity by transport infrastructures (45% of the total) and particularly “Achieving ecological permeability of transport infrastructures”, “Controlling the specific pressures on biodiversity created by the transport sector” and “Restoring and enhancing ecological networks with transport infrastructures”. However, research actions related to improving the general process of transport infrastructure development together account for 25% of themes and the theme “Reduction measures” alone still represents 16% of the occurrence of themes.

Almost all research actions regard the road and railway sectors (97% and 96% respectively), then airports and waterways (88% and 87% respectively), then harbours (80%), powerlines (78%) and pipelines (74%). Hence, the vast majority of research actions show that they are not specific to a single type of infrastructure. This makes possible significant cross-fertilization of knowledge between the different transportation sectors. Road, railway, waterway, airport and harbour sectors are able to share more than 80% of the knowledge acquired thanks to the proposed research actions. Even the relatively least considered infrastructures (powerlines and pipe lines) can share 73% to 77% of the knowledge acquired with the other five.

The most considered life stage among research actions is Operating (91%) which attests to the progress still necessary for this stage despite it has been the most taken into account since the birth of transport ecology. The same applies for Design (79%). Although it entered the field of concerns more recently, the Adapting stage of pre-existing infrastructures now raise also many questions (82%). These 3 steps show to be strongly linked together within research actions (71% to 77%). Although fewer in number, research actions relating to Planning (51%) and Decommissioning (49%) mark a renewal of research questions: infrastructure planning is considered from a broad perspective that

takes into account all the dynamics of the areas it crosses (integrated planning), whereas decommissioning (which opens to rewilding) had hitherto been of little concern to stakeholders. Lastly, the Construction stage raises fewer questions (36% of research actions) but following the life cycle analysis approach, it includes notably effects of the distant processes (e.g. material supply) induced by the construction.

In addition to research actions, the implementation of three tools to improve the effectiveness of research in transport ecology in Europe is proposed. These are: implementation of a data collection system from the mandatory monitoring of transport infrastructures; development of full-scale experimentation projects to test hypotheses and solutions; implementation of a network of long-term study areas across Europe. These tools can help researchers to join efforts on shared topics and objects. They can help cooperation with all stakeholders and information sharing.

Countries in Europe and European ecoregions can engage the research actions adapted to their specific needs. The European Union can guide and facilitate implementation of research actions through its policy and funding. To anticipate this aspect, as part of this work, a reflection has been developed on the research environment today with respect to the topic addressed by BISON and in view of its future support by various sources of funding. European but also national, transnational or cross-industry levels have been regarded, which open on several possible avenues.

The Strategic Research Agenda for more biodiversity-friendly transport infrastructures in Europe is the research side of the BISON SRDA. The content of the SRA (Deliverable 4.2) will be combined and merged with the contribution of deliverables produced by other work-packages to form the BISON Strategic Research and Deployment Agenda. The BISON SRDA will be an essential step in the dialogue and cooperation to be initiated with all the stakeholders concerned by the perspective of biodiversity-friendly transport infrastructure in Europe and in the member states.

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