Territorial risks

SIRMA

STRENGTHENING INFRASTRUCTURE RISK MANAGEMENT IN THE ATLANTIC AREA

Report on Standardization needs for Resilient Transportation: Atlantic Infrastructure

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Territorial risks

SIRMA

STRENGTHENING THE TERRITORY'S RESILIENCE TO RISKS OF NATURAL, CLIMATE AND HUMAN ORIGIN

Application Code: EAPA_826/2018

Report on Standardization needs for Resilient Transportation: Atlantic Infrastructure

WP 3 Capitalization

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SIRMA Project Synopsis

SIRMA aims to develop, validate and implement a robust framework for the efficient management and mitigation of natural hazards in terrestrial transportation modes at the Atlantic Area, which consider both road and railway infrastructure networks (multi-modal). SIRMA leads to significantly improved resilience of transportation infrastructures by developing a holistic toolset with transversal application to anticipate and mitigate the effects of extreme natural events and strong corrosion processes, including climate change-related impacts. These tools will be deployed for critical hazards that are affecting the main Atlantic corridors that is largely covered by SIRMA consortium presence and knowledge. SIRMA's objectives will address and strengthen the resilience of transportation infrastructures by:

- Developing a systematic methodology for risk-based prevention and management (procedures for inspection, diagnosis and assessment);
- Implementing a decision-making algorithm for a better risk management;
- Creating a hierarchical database (inventory data, performance predictive models, condition state indicators and decision-making tools), where information can be exchangeable between entities and across regions/countries;
- Developing a real-time process for monitoring the condition state of transportation infrastructure;
- Enhancing the interoperability of information systems in the Atlantic Area, by taking account of data normalization and specificity of each country.

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Executive Summary

Translation of new research methods, insights and interpretation of results to practice requires assimilation of findings into clear guidelines and recommendations that can be adapted easily to a wide range of scenarios and in a robust manner. This report outlines how the research outcomes of SIRMA can lead to guidelines and recommendations, which in turn create a conduit towards contribution to a standardisation process. Standardisation needs as a result of the project is also highlighted. To this effect, the overall needs are contextualised and subsequently examples are created to demonstrate how to maximise exploitation of SIRMA results towards a standardisation process. The report also leads to future examples and impacts that can be achieved in the medium and long term after the completion of the SIRMA project. This report should be read in conjunction with the deliverables, reports and results created from the SIRMA project and hopefully for future projects to create a common outline and interpretative framework.

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1. Introduction

While there has been extensive research globally on natural and anthropogenic hazards, there is an ongoing and strong need to translate the findings to robust guidelines and recommendations, which can be used by a range of stakeholders of built infrastructure to ensure safety and serviceability over lifetime. Not only does this lead to safer and more resilient infrastructure over lifetime, but it also allows for better adaptation of analysis, design, assessment and decision making of these structures for a wide range of environments and performance demands. Consequently, the connection of ongoing research to an eventual standardisation process is paramount.

This need, especially in the context of infrastructure assessment, has been recently addressed by the EU Cooperation in Science and Technology (COST) Action TU1406 (Wenzel and Pakrashi, 2019): Quality specifications for roadway bridges, standardisation at a European level (BridgeSpec). Subsequently, the EU organisation Eurostruct (www.eurostruct.org) was developed, championing the cause for guidelines and recommendations (includign task groups). While there exists a wide avenue of organisations engaging with this process in various capacities (including the more detailed CEN/CENELEC groups to various IABSE Task Groups and activities of Joint Committee of Structural Safety, and even the works around the Globe consensus). With the various organisations and activities around standardisation, there is not only thus an opportunity to engage with some of the processes but also around the level at which results from SIRMA can be engaged with such processes.

Apart from safety and performance, another core area of understanding (or the lack thereof) is the concept of resilience. While this is a popular word, the interpretation, use and estimation of it can be often qualitatively and quantitatively different to different people. Under such circumstances, the translation of various works to a tangible and interpretable around resilience is also important. To this extent, Pakrashi and Martinez-Pastor (2020) nationally discussed some aspects and challenges around transport network. There is a need to clarify methods of defining and estimating resilience.

Risks, be they natural or anthropogenic, are often estimated not just by design but also by monitoring. Often, their effects are better translated by monitoring damage and subsequently estimating what the remaining strength or performance aspects might be, providing the stakeholders with a clear view of what is needed. Monitoring thus relates to a more direct assessment of the consequences of risk, allowing for better decision making.

The subsequent sections in this report first investigate the context and efforts around standardisation, guidelines and recommendations around the Atlantic Area and focus then in detail around the SIRMA project. Three different examples (2 academic and 1 non-academic participants) are considered in this regard following a workshop and discussion in the 5th SIRMA Meeting in its Dublin workshop.

It is expected that the examples and the method will provide not just outcomes of how SIRMA results can engage with an overall standardisation process, but also how other results and projects can benefit from such efforts. These examples and the report also open an avenue of further discussion and debate around making this process more robust.

2. Efforts of Standardization of Infrastructure Resilience involving the EU Atlantic Area

2.1 Standardization needs and context

The challenges of today's built infrastructure is complex since the structures are degrading and the assessment, operations or decisions on existing structures is not straightforward. While design has many standardisation aspects, the impact of hazard and their consequences often bring in unique situations for which guidelines and recommendations require constant development. These needs can be anthropogenic or natural. Consider Figure 1, which represents the monitoring of a bridge struck by a truck (Pakrashi et al., 2013), while Figure 2 represents the underside of a bridge in Ireland naturally corroded over time due to exposure to saline marine environment. The maintenance, assessment and decisions over such situations remain evolving.

While there are codes, and there is provision to carry out structure specific analyses in codes, the evolution of some of the assessments, in an individual or a stock level can significantly vary (Hanley et al., 2018). Under such circumstances, there is always a continuous need to engage with the standardisation pathway at national or international (e.g. EU) levels to ensure that the interpretation and implementation of new ideas, concepts or solutions can be established as widely as possible, leading to maximised impact.

Figure 1: Repair and Monitoring of a Bridge hit by a Truck

Figure 2:Naturally degraded underside of a bridge following long term exposure to marine environment

On the other hand, newer concepts like resilience have not seen adequate translation to practice and there is a need for a clear formalism of it over time. At least, there needs to be a clear idea around a common definition when implementing, comparing and discussing them.

There are also challenges around the vocabulary of various degradation, action items and markers, along with the interpretation of methods. The specific implementation of various methods and markers may vary from one network or asset to another, but some of the fundamental tenets should create a framework and an overall guideline, recommendation and eventual standardisation.

SIRMA project has considered this context around its creation of results and future exploitation around the standardisation aspects. The outcomes link to risk and performance of the structures and the subsequent sections show how some of these guidelines were obtained.

2.2 Examples of Standardisation pathways

The standardisation pathways are several and related to national and international needs. There are also questions on timelines of arriving at such an outcome and core questions on the acknowledgement, interpretation and estimation of risks and uncertainties evolved with the process. While the timeline of creating standardisation is very long and may well run into more than a decade, it is easier to continue to engage with the process through the results feeding into relevant bodies for use and further probing. This makes the context, need and impact evolving and ensures that the outcomes and results of a project are well represented beyond their lifetime.

In EU, there are specific groups around codes (consider CEN TC250 WG2 for example, related to the assessment of structures, or CEN TC350 engaging with sustainability and construction works) where outcomes and results can feed in to, but often such ideas have to be more mature than individual projects. There are task groups from Eurostruct, International Association of Bridge and Structural Engineering (IABSE) or Joint Committee of Structural Safety (JCSS) where engagement can lead to a wider uptake of the idea and can be translated better to practice. There are national bodies (e.g. National Standards Authority of Ireland) which can also be particularly beneficial.

Irrespective of these aspects, standardisation remains a slow activity and it can often be easier to implement it within national and international networks, through engagement with owners or managers of these infrastructure networks, or co-creation with them. In SIRMA, and projects like SIRMA the co-creation aspect has been important and it is particularly important to translate the results to a wider range of people. Consequently, this direct translation to a practising environment has been a focus of SIRMA to ensure that the implementation and interpretation of the methods and results thrive in real-life examples and also create the right environment for continuing through standardisation efforts through multiple avenues.

Risks around infrastructure are multifaceted and continue to grow. Even in the context of extensive IPCC reports (e.g. Dodman et al., 2022), the standardisation and guidelines and recommendation needs keep distending. The risks are evolving and so are their fundamental understanding, there are challenges around definitions and semantics, the methods are many and deep but their common understanding needs improvement to better interpret the results and a common ground is often a challenge to establish. With so many challenges, communication of results to standardisation bodies often go beyond standard formats that we are used to. Under such circumstances, examples and results from several projects can address how this effort can be better supported.

SIRMA project has considered this and has approached the problem with several academic and industrial partners, leading to a number of examples, as shown in Section 3 of this report.

2.3 Current examples of standardisation efforts

Over time, we do see newer standardisation aspects, even for relatively newer ideas. Consider the example of VDI4551: Structure monitoring and assessment of wind turbines and offshore stations which was recently published. There are Eurocode groups active in EU, and some of the efforts have been discussed in this report, as has been the relevance of national bodies.

The efforts of bodies like IABSE, Eurostruct, JCSS etc. in engaging with such process are also noted in the previous sections, as are the COST Actions (e.g. TU1406, or TU1402 on value of Structural Health Monitoring) in being catalysts for this purpose. Current efforts around such assessment are also functions of new technologies and approaches, Here projects like SIRMA are particularly beneficial, as are recent projects like IM-SAFE (https://im-safe-project.eu/).

To continue with this engagement with standardisation, a brief SWOT analysis is presented below in Table 1.

Strength ● Translation to practice is the best way to improve and impact the lives of citizens and these industry-academia interdisciplinary groups can be very effective ● The results provide an excellence benchmark and evidence base for creating the standaridsation processes	**Weakness** ● The process can be very long with low integration with actual standards being produced ● While being adapted to a standardisation process, several recommendations and guidelines can be more vague to accommodate various circumstances.
Opportunities ● The projects are more reactive to fast changing aspects like technologies and their results, creating directions of how standardisation aspects move ● The quantitative aspects of many calibrations can come from projects like SIRMA in terms of current and future risks	**Threats** ● Overlooked unknowns can lead to life and economic risks ● Disengagement with the process increases uncertainties and interpretation of findings, leading to low exploitation of results ● Exploitation of many technologies will be sub-par without this engagement

Table 1:A SWOT Analysis around the Engagement of projects like SIRMA with standardisation, guidelines and recommendations

3. A Demonstrative Pathway Towards Standardization

3.1 Methodology of Standardisation Needs Identification

The method of creating responses of standardisation needs and identification of them from SIRMA results was organised in two steps. First, the 5th Workshop of SIRMA was held in Dublin, engaging different stakeholders and partners. This subsequently led to discussions and a questionnaire (Appendix A) was developed which overall guided these efforts. Next, some of the more evolved and connected activities around this standardisation was integrated and collated in this report in Section 3.2 to demonstrate how the overall approach can be relevant for quite different activities. The work leads to academic and industrial responses and a total of 3 examples are presented here to showcase the efforts. It is important to note here that the emphasis is in aligning the existing results to possible guidelines, recommendations and standardisation efforts from a range of activities in future for maximum exploitation of results, rather than trying to create such a standardisation - which would be ineffective. Thus, the creation of possibilities for translation to practice remains important here.

3.2 Examples Standardization Needs Identification

Some further examples are presented from 2 academic and 1 industrial partners in SIRMA to develop and detail a framework to create this need and efforts around standardisation, but within the overall framework of querying and understanding. These examples are presented for future works to adapt themselves to a similar unified approach. Note how such an approach can create a better understanding of the needs and pathways, despite the innate variabilities in the responses, as they are expected.

Academic Partner 1

University of Birmingham

Impact of work on guidelines and recommendations:

Planning towards future transport infrastructures requires considering adaptation actions to protect the transport systems against negative impacts of climate change and extreme weather events, while also developing resilient infrastructure. This SIRMA project has explored, reviewed and analysed past extreme weather events leading to floods and wildfires and their corresponding effects on different transport infrastructures (mainly roads, railways, bridges and slopes). Work Package 6 (Risk & Resilience-Based Decision Making procedure for Transportation Infrastructure) has led to the development of relational databases which present the most relevant risk mitigation (adaptation) measures identified, based on a number of parameters such as the effectiveness, costs, and time-frequency of the most common adaptation measures. The databases presented in the Deliverable report D6 (Transportation infrastructure risk-based management) offer a unique collection of different case studies investigated that showcase adaptation measures which have already been carried out or are being implemented to increase resilience of transport infrastructures to extreme weather events. The databases also report the respective lifetime span of the measures discussed, the component of risk which is mitigated by implementing the measure, along with the associated direct and indirect costs as well as the impacts of the measures.

Emphasising where SIRMA work can extend or clarify existing standardisation of guidelines and recommendations:

The produced relational databases in the Deliverable report D6 (Transportation infrastructure risk-based management) can be used to develop frameworks that inform, highlight and collate the presented examples to bring together best practices which can be tailored to local needs and strengths. It is expected that the dissemination of these databases along with the research outputs of the current SIRMA project will raise awareness of what is possible and inspire the creation of new activities to deal with observed and expected climate change impacts. The current policies and guidelines on transport adaptation encourage best practices, mainstreaming adaptation within the transport infrastructure development programmes. Therefore, the current SIRMA project and its outcomes such as the databases can be utilised as potential sources of guidance for adapting transport infrastructure.

How can we use SIRMA results further to be useful for resilient transportation?

- One of the major outputs of this work are the two complete and accurate relational databases in the Deliverable report D6 (Transportation infrastructure risk-based management) that provide a set of suitable risk mitigation measures for transport infrastructures against floods and wildfires. The databases also provide a brief explanation in what circumstances the listed adaptation measures should be used, the component of risk that the measures can mitigate, their respective lifetimes, impacts and the costs needed for the implementation of such measures. All costs are provided in Euros. Such databases can be very useful for asset managers and different transport related stakeholders as the outputs of this SIRMA work can be treated as a guidance for dealing with climate change and similar challenges.

- Another output of this work is the demonstration of the outcomes of the disseminated risk mitigation measures questionnaire in the Deliverable report D6 (Transportation infrastructure risk-based management). To develop a decision-making procedure based on resilience, it was considered necessary to collect information on risk mitigation measures to be incorporated into a risk-based predictive model. To this end, a questionnaire was developed to obtain feedback from specialists dealing with transport infrastructure management on the effectiveness, costs, and time-frequency of the most common risk mitigation measures. The survey intended to collect, from experts dealing with transportation infrastructure management, a list of the most relevant risk mitigation measures and their characteristics that can be adopted for extreme natural hazards, namely floods and wildfires. The results of the survey are now being used to develop a user-friendly software, and corresponding algorithm, for the multi-criteria decision-making, i.e., by maximising resilience and minimising the risk mitigation measures costs. A manual that complements such software will be also delivered. It is also expected that the outcomes of this work will assist in the development of a risk-based framework for real-time decision-making in transportation infrastructures management. The short, medium, and long-term decision-making, concerning the optimal planning of risk mitigation measures for transportation infrastructure, will be respectively attained with the developed risk-based framework for real-time decision-making.

How are SIRMA results linked to policy or implementation practice?

On the European level, transport sector policies are usually focused on climate change mitigation and the reduction of the environmental impacts of the transport sector. This does benefit adaptation, but not specifically. However, based on the systemic nature of the EU Strategy on Adaptation to Climate Change, adaptation actions in transport will be implemented in an integrated manner with other European Green Deal initiatives such as Sustainable and Smart Mobility Strategy. These strategies and plans lay down the foundation on ways the EU transport system can attain its green and digital transformation while becoming more resilient to climate change. The outcomes of this present SIRMA project and particularly the Work Package 6 (Deliverable report D6: Transportation infrastructure risk-based management) highlight the need for climate-proofing EU Transport Network, which is also a part of the guidelines for the development of the Trans-European Transport Network that states the need for developing efficient, safe, smart and sustainable transportation that addresses climate change. The European Commission’s Adaptation White Paper has also highlighted the importance of adapting transport systems to the impacts of climate change. Currently, a mix of policies on European transport, climate change and research are addressing the need for transport adaptation. In addition, the EU also encourages best practices, mainstreaming adaptation within its transport infrastructure development programmes, and provides guidance. Therefore, the SIRMA Project’s Work Package 6 outcomes can also be utilised as a potential source of guidance for adapting transport infrastructure. This work can contribute significantly to improving the existing knowledge base on transport adaptation.

What is the meaning/interpretation/definition of the word ‘resilience’ to you in SIRMA?

Resilience refers to the ability to continue to provide services when a disruptive event occurs (CEN, 2021). It also indicates the capacity of a system exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (UNISDR, 2009).

Industrial Partner 1

AZVI

Impact of work on guidelines and recommendations:

Azvi's work in this project has been based on our experience in road and railway line maintenance work, especially in the area of southern Spain (Province of Seville), whose climate is characterised by droughts and very high temperatures, which frequently cause the activation of weather alarms for extreme temperatures.

The work carried out by Azvi in this project has focused on the workers who have to apply the mitigation measures in their daily maintenance work, and who therefore have the knowledge to identify and evaluate the most useful adaptation measures. Therefore, the impact of the work carried out by Azvi's experts (highway and railway maintenance managers) has improved the definition of mitigation measures to hazard, vulnerability and consequences due to flood and wildfires on bridges, slopes, road pavements and railway tracks.

Emphasising where SIRMA work can extend or clarify existing standardisation of guidelines and recommendations:

Previous to the beginning of the SIRMA Project, it was difficult to find publications by official entities in Spain about climate change in transport infrastructures, unlike in health, agriculture or other economic sectors.

In this sense, one of the documents available was the report "Necesidades de adaptación al cambio climático de la red troncal de infraestructuras de transporte en España (2013) " issued by El Centro de Estudios y Experimentación de Obras Públicas (CEDEX), dependent on the Ministry of Transport, Mobility and Urban Agenda. This document refers to high-level strategies to combat climate change on roads, railways, ports and airports. However, the report does not define concrete action measures for infrastructure maintenance works.

The difference with the work carried out in this project is that SIRMA has identified and evaluated concrete measures of direct application in construction and maintenance works in road and railway infrastructures.

How can we use SIRMA results further to be useful for resilient transportation?

Database with effects and costs of risk mitigation measures, based on the Risk Mitigation Measures Questionnaire may be a key tool for day to day maintenance companies. And also, for civil engineering companies working on construction projects design.

How are SIRMA results linked to policy or implementation practice?

Our SIRMA work can be linked to The Spanish National Climate Change Adaptation Plan 2021-2030 , in which Mobility and transport chapter says that it is necessary to integrate resilience to climate change into the life cycle of infrastructures (designed to last 50 years or more), as well as to adopt adaptation measures to ensure their availability and operability facing the impacts, especially those arising from the increased intensity and frequency of certain extreme weather events, and minimising their economic, environmental and social costs.

What is the meaning/interpretation/definition of the word 'resilience' to you in SIRMA?

From the point of view of a company in the road and rail maintenance sector, for us the resilience of infrastructures is linked to the time they have to be out of operation due to the causes of climate change. In this sense, our objective is to achieve resilient infrastructures that are less affected by the impacts of climate change and can therefore be operational as soon as possible, minimising their economic, environmental and social costs.

Based on the Spanish Royal Academy resilience definition : capacity of a material, mechanism or system to recover its initial state when the perturbation to which it had been subjected has ceased.

Academic Partner 2

Universidade de Vigo

Impact of work on guidelines and recommendations:

Currently, there is a lack in standardisation on inspection, monitoring and testing of in-service civil structures as only very few European countries have published guidelines or codes to address the data collection and analysis. These existing documents are published with the aim of guiding users with general information about certain proven technologies, surveying activities and some data analysis towards standardised measures. This means that these existing standards or guidelines do neither sufficiently address the vast amount of condition survey technologies that have emerged in the last years for infrastructure monitoring and inspection, nor properly guide on the analysis and processing of the information recruited. For that reason, the existing guidelines do not resolve the complex combination of decisions that would result into gathering relevant and sufficient information about the condition of the structure for the purpose of asset management. This hinders asset owners and public authorities in charge of maintenance of the transport infrastructure to apply the latest developments.

Emphasising where SIRMA work can extend or clarify existing standardisation of guidelines and recommendations:

Within the context of SIRMA project, and specifically WP5, UVigo has been working in reviewing data collection technologies and data analysis methods used in condition survey (including inspection and monitoring) and identifying their requirements for complex environments such as inland transport infrastructure. The data collection technologies investigated and tested by UVigo mainly refer to remote sensing technologies, both terrestrial and satellite. The data analysis that include both data pre-processing and advance analysis were evaluated from the point of view of automation, this is, developing ad-hoc automated processing tools and services in order to be applied to specific to transport infrastructure assets, namely roads and bridges.

In the context of WP5 UVigo has developed a report about remote sensing technologies for the inspection and monitoring in the domain of inland transport infrastructure. This report collected information about surveying technologies used for condition survey to meet the requirements that can be expected in resilience-oriented infrastructure management. In that sense, an output of the SIRMA project consists of an exhaustive review of emerging technologies and the corresponding protocols for data acquisition and analysis towards the extraction of meaningful performance indicators (PI). These PI are not only for the condition state of the infrastructure assets, but also in terms of resilience (linked to the anticipation of disruptive events).

The main contributions of SIRMA project and the aforementioned report compared to the existing guidelines in conditions survey are:

A review of data collection technologies used for condition survey, including devices and platforms for the following technologies:

- Satellite technologies, including optical and radar monitoring
- Aerial und UAV technologies, including optical and NDT payloads
- Terrestrial dedicated inspection platforms, including GNSS, IMU, cameras and LiDAR

How can we use SIRMA results further to be useful for resilient transportation?

The data collected with the aforementioned monitoring technologies does not directly provide resilience indicators. Instead, the information extracted after the data analysis can result in useful inputs for structural assessment and model updating. For example:

In the case of roads, mobile mapping inspection with LiDAR systems allowed to automatically compute:

❖ Pavement condition measured by the presence of crack and other superficial distresses. These can be parameterized through:

- Area occupied by cracks (in %) per km.
- Other geometric indicators can be adopted: average crack length (m). Average crack width (m), etc.

❖ Vulnerability to forest fires: this is computed through a risk index in a scale between 1 and 5 (being 5 highest risk level).

In the case of critical assets such as bridges, the monitoring technologies proposed by UVigo in WP5 allow to compute:

- Creation of numerical model of the structure with the actual geometry (units m).
- Calibration of the numerical model using experimental dynamic data (natural frequencies and modal shapes). Depending on the case study, the influential parameters may change (we perform a sensitivity analysis) and thus, the corresponding units (eg. Young modulus, stiffnesses, etc.).
- With the calibrated model, we can update the reliability index of the structure.

The indicators explained in the previous section are the direct outputs of remote sensing monitoring technologies and can be used for the assessment of resilience through the decision making methodology. Depending on the approach followed, these PI can:

1) Using Risk Analysis:

a. Be used to quantify vulnerability of the infrastructure/asset.

b. Be used to quantify probability of failure (eg. using the Reliability Index in bridges)

2) Be used to quantify resiliience KPIs, namely indicators related to maintenance costs.

How are SIRMA results linked to policy or implementation practice?

The SIRMA knowledge in condition survey technologies is contributing to the H2020 IM-SAFE. This project is a Coordinate and Support Action whose final goal is to inform the new European standards for monitoring and maintenance of the structures, thus closing the gap between the standard and the practice with regard to the monitoring of structures. The knowledge generated in SIRMA about infrastructure monitoring using satellite radar images is being transferred through IM-SAFE project.

What is the meaning/interpretation/definition of the word ‘resilience’ to you in SIRMA?

The UN defines resilience as: “The ability of a system to resist, adapt to, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.” (UNDRR Glossary, 2017).

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3 https://dle.rae.es/resiliencia

SIRMA

STRENGTHENING THE TERRITORY'S RESILIENCE TO RISKS OF NATURAL, CLIMATE AND HUMAN ORIGIN

Application Code: EAPA_826/2018

Report on Standardization needs for Resilient Transportation: Atlantic Infrastructure - Appendices

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PUBLIC

Appendices Contents

Appendix 1. Questionnaire Shared with Partners to Develop Demonstrative Examples to create future Standardization Pathways

The following questions and commentary were developed and circulated amongst relevant partners to obtain responses, following the 5th SIRMA Workshop and Meeting. This helped identify, discuss and clarify some of the example pathways towards standardisation needs as presented in this report.

Questions

PART 1

Impact of work on guidelines and recommendations:

i) Summarise the impact of your work on guidelines and recommendations (on the topic that your work covers) [Part 1]

PART 2

ii) Emphasising where your work can extend or clarify existing standardisation of guidelines and recommendations [Part 2] (this contextualises Part 1 against existing documents like codes or other similar normative documents that are followed)

Compare SIRMA work with existing guidelines/recommendations/normative documents and how your work can/has influenced this through what you said in PART 1

PART 3

iii) From your results in SIRMA, what output results (e.g. reliability index, cost, some other safety or serviceability index, but please include the unit of it) can be used for computing resilient transportation and how? [Part 3] In the 'how' part - I intend to ask if your result can be used to connect to a certain decision making, or a certain model etc. We are trying to say: *how can we use the results further to be useful for resilient transportation*?

List of relevant outputs of your work and how to use them practically for resilient transportation.

PART 4

iv) Can you link your results to any policy or implementation practice that is actually done in our country/another EU country (or even outside EU)? [Part 4]

How can/has your SIRMA work influence/d practice or implementation or policy in a country/countries: (it can also be possibilities in future – but please be specific – the other parts have covered the generic parts)

PART 5

v) The word *resilience* can often have a wide ranging interpretation. Please feel free to indicate in a couple of sentences or with a reference - what *resilience* means to you?

What is the definition of *resilience* based on which you are reporting this.