Proceedings of the 19th Conference on Computer Science and Intelligence Systems (FedCSIS) pp. 513–524 DOI: 10.15439/2024F7655 ISSN 2300-5963 ACSIS, Vol. 39

A framework for enabling ex-ante social impact assessment of project-based technological solutions: the case of Remote Infrastructure Inspection

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***Abstract*— Social Impact Assessment (SIA) is the systematic examination and management of both the intended and unintended social consequences, encompassing positive and negative outcomes, resulting from designed interventions (such as policies, plans, or projects) and any social changes instigated by these interventions. In this paper, we present a strategy to define and validate social impact indicators incorporating participatory approaches into the general impact assessment framework. The paper reports on the first results of an ongoing SIA developed for the evaluation of the impact produced by a Remote Infrastructure Inspection (RII) toolset developed to increase the resilience of critical infrastructures within the framework of the SUNRISE Horizon Europe project. Several stages of the indicators' selection procedure were proposed to ensure the validity of the selection. Our approach is then applied to identify social impact subcategories within the RII Toolset, aimed to introduce less effort-consuming ways of inspecting typically large infrastructures.**

***Index Terms*— Social impact assessment, impact indicators, remote infrastructure inspection.**

I. Introduction

THE COVID-19 pandemic revealed that European societies highly depend on the uninterrupted supply of essential services during global crises, especially during pandemics. These essential services encompass various systems such as energy and water supply, transport networks, health and social services. These services are referred to as critical infrastructures (CIs) due to their importance to society.

This work was funded by the European Union through the Horizon Europe research programme under grant agreement n◦101073821 (SUNRISE)

The resilience of critical infrastructures (CIs) during such events is crucial for maintaining societal stability, public health, and economic continuity. In this context, resilience refers to the ability of critical infrastructure systems to prepare for, withstand, recover from, and adapt to adverse conditions. It is of paramount importance that European CIs possess resilience, the capacity to adapt to evolving risks and the ability to swiftly recover from both anticipated and unexpected disruptions. However, European CI operators and public authorities are still not fully prepared to address the risks as the threats are swiftly evolving, while the interconnectedness of CIs in Europe has become increasingly complex and digital. In practice, this implies that disruptions in a single CI can increase social, economic, and environmental impacts across other CIs, regardless of the sector of operation.

The SUNRISE project was funded by the EU to address these issues, ensuring the availability and continuity of critical services in Europe through the introduction and deployment of several technological solutions aiming to provide greater adaptability and reliability of CIs. The project, running from October 2022 to September 2025, involves 41 partner organizations, including public and private CI operators, authorities, and technology developers.

Any technical solutions, depending on their purpose and way of operation have the potential to affect the well-being of various groups of people, i.e. individuals, communities, and the society as a whole. At times this impact is direct and intentional: e.g., a technical solution to enhance the economic performance of a company has a direct impact on its financial indicators. However, other kinds of impact are not directly visible or identifiable: e.g., teleworking tools while allowing performing professional duties from various locations, may affect the communication patterns of the employees their work-life balance, and other social aspects, such as the emergence of a feeling of social isolation.

According to The International Principles for Social Impact Assessment, SIA can be defined as "the processes of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by those interventions" (p.5) [1]. This definition suggests that social impacts encompass a broad range of planned and unplanned consequences caused by a project, while the affected people may include various levels of stakeholders ranging from individuals, and social and professional groups, to the communities and society at large [2]. Besides, SIA is crucial to project organisers, reinforcing their social missions, objectives, and strategies [3].

Thus, the need for a balanced assessment of social aspects of planned intervention is of paramount importance to consider carefully all the possible groups affected and define the key areas of impact through a thorough estimation of indicators, which provide measurable and objective data for informed decision-making. Otherwise, the outcomes of inaccurate evaluation - e.g., priority areas, predicted impacts, measures of significance, etc. - could be either biased or misleading, and may not necessarily reflect stakeholders' values and beliefs [4]. Given that the setting of each project, specifics of proposed solutions and nature of impact vary a lot for each planned intervention, SIA cannot be initiated with a ready-set checklist of possible impacts. It is necessary that the set of impacts is identified "from an awareness of the project and an understanding of how the project will affect what is important to the project's stakeholders" (p.2) [2].

While an increasing number of projects consider the importance of SIA, many of them encounter difficulties in choosing the most suitable strategy and set of methods that align with the unique requirements of a project [5]. A significant challenge for projects lies in the determination of what impact metrics to apply, and what indicators to measure and report [6]. This complexity extends to the manner in which SIA indicators are defined and verified, especially in the context of planned implementation of technological tools not yet in place. There is a notable research gap in the current approaches, which are often highly case- and technology-specific in relation to indicator lists' definition, paying little attention to the processes of identifying impact categories and validating their results [7]. There is another research gap in the existing SIA methods and frameworks that support technological solutions, as the ex-ante stage of the assessment is often regarded as a subsidiary component of the assessment [8].

While this stage can be regarded as initial and not bringing the final results, it establishes a foundation for further steps and forms an impact category framework for the whole SIA of a project.

The objective of the study is to identify how an adaptive and participatory SIA framework can be developed to inform and improve the deployment of project-based technological solutions not yet deployed. The article presents the results of the framework elaboration process, discussing the set of assessment stages adaptive to the requirements and limitations of the project and adjusted to the toolset's development stages. These stages enable the implementation of a specific yet versatile set of consecutive and analytical steps. Using the example of one technological solution developed within the SUNRISE project, the paper discusses the first stage of assessment, which allows the provision of feedback to key stakeholders and adjustment of the tool prior to the testing and deployment stages. The ex-ante evaluation procedure advocates the assessment based on the project scope, outputs, and stakeholders directly involved in tool development, defining and verifying the relevance of impact areas and dimensions. Building upon these focal points, interim results of the assessment are discussed with a set of key issues identified to increase the social sustainability of the project.

The article is organized in the following way. Section 2 provides background information on the SUNRISE project, presents a specific technological tool of this research (a tool for RII) and reviews relevant literature on social impact assessment methodologies and theories. Section 3 sets out the general SIA framework of SUNRISE, explains the ex-ante strategy used to conduct the social impact assessment, and discusses data collection methods (surveys and focus groups) applied. Section 4 presents the findings of the SIA and describes the identified social impact categories of the project. Section 5 interprets the results of the ex-ante assessment in the context of the project and their social implications, provides an analysis of the significance of the identified social impacts, discusses the potential implications for stakeholders and affected communities, and addresses limitations and challenges encountered during the assessment. Section 6 concludes by summarising the main findings of the SIA, suggesting practical applications, and areas for further investigation.

II. The Context of the Sudy

A. *The SUNRISE project*

In the context of COVID-19, European CI operators and public authorities have been faced with numerous challenges in managing the risks of future crises, as threats continue to evolve rapidly [9]. These challenges include the lack of collaboration among CIs; the absence of thorough risk evaluations; a scarcity of specific strategies and measures to maintain operations during a pandemic; and a shortage of resilience-oriented tools available before and during the crises. To address these challenges, the SUNRISE project has targeted five key objectives[1]:

[1] https://sunrise-europe.eu/about

- To promote dynamic cooperation among European CIs, spanning various sectors, and involving both public and private entities.

- To identify services and CIs that are crucial during a pandemic, understand their interconnections and dependencies (including risks of cascading effects), and devise effective mitigation strategies.

- To produce a strategy and a suite of advanced technologies to ensure CI resilience and business continuity during a pandemic.

- To test the newly developed strategy and technologies in real-world settings throughout Europe.

- To promote a resilience-oriented approach within and across European borders.

The project's consortium includes 18 public and private CI operators and authorities from various sectors (energy, transport, health, digital infrastructure, water supply, and public authorities) and countries, including EU Member States as well as EU-associated countries.

The project aims to develop a suite of new technologies and applicable solutions, including Risk-Based Access Control tool (a tool that minimizes risk when accessing critical infrastructure in a scalable, privacy-preserving manner; Resource Demand Prediction and Management tool (a flexible tool designed to handle changing demands for resources during emergencies, regardless of the specific critical infrastructure); Cyber-Physical Resilience tool (this tool detects anomalies, issues alerts for incidents, provides appropriate responses, and conducts real-time risk assessments for critical infrastructure); and Remote Physical Infrastructure Inspection tool (a tool that uses satellite images, unmanned aerial vehicles – UAVs - with various sensors, and performs machine learning identification to detect anomalies and thus to continuously inspect physical infrastructure)[2].

B. A tool for Remote Infrastructure Inspection

The latter technological toolset (RII) was selected as a case study for the present article for several reasons. First, it combines the modules (discussed below) that are increasingly raising concerns about their application in relation to social impact [10] and potential misuse of obtained information [11]. Second, the societal advantages of obtaining high-definition data should be thoroughly balanced against societal concerns such as privacy [12], which implies an overarching prominence of an appropriate SIA for such technological solutions. Moreover, the ethical use of RII solutions is highly dependent on the setting in which they are used [13], which highlights the prominence of impact evaluation and management, specifically within the context of an international project and multiple CIs involved (seven utilities in transportation, water and energy supply, and telecommunication) in the RII tool's development, testing, and deployment. Given that the SIA framework proposed in this article was created for the entire suite of SUNRISE tools (four technological solutions), its application in such a specific context of RII informs the manner in which it might be adapted to other settings, demonstrating the replicability on other technological solutions.

RII tool, developed in the context of SUNRISE has as a main aim to introduce less effort-consuming ways of inspecting typically large infrastructures (which necessitates the allocation of considerable resources to the physical infrastructure inspection). To do so, the tool aims to provide a more comprehensive view of the infrastructure and its surroundings, allowing inspectors to assess large areas efficiently and frequently. It consists of two main approaches, which are divided according to their vicinity to the infrastructures: the use of satellite imagery for infrastructure inspection (from afar) and the use of UAV (drone) imager to inspect the infrastructure. Both modalities are supported by artificial intelligence (AI) tools, able to sift through the acquired data and provide the focus on potential anomalies, thus alleviating the CIs of manually checking the acquired data. Furthermore, the use of certain modalities (e.g. satellite imagery) with the pre-trained AI models allows for efficient prediction of certain features (e.g. vegetation height, which needs to be controlled to comply with clearance requirements and ensure safety conditions), that are very hard to predict manually. In this way, the infrastructure is continuously monitored in a non-invasive manner.

Typically, the entire infrastructure is controlled by satellite imagery, responsible for detecting any adverse events. However, satellite imagery, despite very high spatial resolutions, remains limited in the precision of results it can provide for the inspection of critical infrastructure. Thus, they are used as a trigger to activate the more costly and labour-intensive UAV-based inspection, which offers a more targeted, localized area-focused monitoring of regions of interest. UAV-based methods work on the acquired imagery and offer a more detailed view of the state of the infrastructure. The AI involved in both methods is from the field of Computer Vision and is capable of predicting the height of vegetation, and detecting changes and states, including the condition of insulators in critical infrastructure. In this sense, it points out anomalies, avoiding the need for human operators to carry out continuous and tedious inspections in the field, and enabling them to focus directly on interventions. As a result, this AI-based tool optimises inspections and interventions.

By introducing these tools, various social aspects are expected to be impacted (e.g. safety, well-being, and privacy), highlighting the importance of conducting a comprehensive SIA.

C. Review of relevant literature on social impact assessment theories and methodologies

SIA is a discipline within social science that aims to provide insights into the vulnerabilities, risks, capacities, well-being, and resilience of various groups of people. It offers valuable information for designing planned interventions that enhance potential risk reduction, resilience, and social sustainability [14] – [17].

[2] https://sunrise-europe.eu/about

SIA involves the evaluation, monitoring, and management of both positive and negative social consequences that projects may have on the well-being of individuals, specific groups of people (e.g. workers) and communities [2]. The development of the SIA discipline has been closely associated with a project-oriented context, applied to enhance positive outcomes and minimize negative social effects of planned interventions [18]. To provide an appropriate evaluation, the SIA process is recommended at each key project phase [2]. Therefore, impact assessment practitioners should consider the specific context of a project-based evaluation (specificity of a project form, e.g. phases, timeframe, location, etc.) as well as intervention characteristics (product, technological solution, physical construction, etc.). The following paragraphs present the SIA specificities of a project and remote infrastructure technologies to which the SIA will be applied.

A project is recognized as a form of transient organisational structure that is becoming increasingly prevalent in contemporary society, where "resources are assigned to undertake a unique, novel and transient endeavour managing the inherent uncertainty and need for integration in order to deliver beneficial objectives of change" (p. 7) [19]. A project, during its lifespan, adheres to a set of meanings, holds specific values, and operates on a philosophy shaped by the consortium's relationships [20], usually reflected in the project's guidelines and proposals. According to Bakker et al [21], the success of a project fully depends on the precise definition of priorities, management procedures, and strategic methods to address issues effectively. Such effectiveness should be understood in broad terms, considering changes beyond overcoming the technical challenges (reaching defined goals), and encompass various areas that the planned intervention may affect, including the social domain.

Many studies have discussed the evaluation of the social impact within projects [22]. According to Passani [23], within the context of the organisational form of a project, an appropriate impact assessment strategy (including SIA) requires analytical rigour to ensure the validity of the evaluation; several iterations of assessment throughout all phases of the project; appropriate data collection methodology accommodating the analysis of differences in impacts; and specific budget to ensure proper execution of the assessment.

In order to consider these general requirements, a proper project-based SIA framework needs to be set up. According to Vanclay et al [2], the established good practice SIA comprises four phases: understanding the issues; prediction, analysis, and assessment of the likely impact pathways; development and implementation of strategies; and design and implementation of monitoring programmes. The authors highlight that due to the context of a project, these phases are "somewhat sequential, but which also overlap" (p. 7) and need to be adjusted (ibid). Indeed, as each project has its own context and setting it is hard to present a pre-defined framework that fits any planned intervention, the modifications in more precise stages of assessment as well as methods selection need to be made by SIA practitioners. In particular, corrections of an ongoing evaluation deserve special attention: "Through data collection and analysis, SIA is a learning process, and consequently initial assumptions and preliminary understandings may need to be modified in the light of new information, so there needs to be an iterative process of validation and update informed by an on-going process of consultation with project proponents and other stakeholders" (ibid, p.7). Such a perspective is relevant for all the dimensions of a project (e.g. its scope, area, stakeholders, etc), however in the context of SIA framework elaboration, where execution steps should be based on a realistic understanding of the project's potential impacts [23], impact areas identification and validation take on particular significance.

D. The social impacts of Remote Infrastructure Inspection solutions

While the technical effectiveness of UAVs and satellite imagery to tackle operational issues of CIs is rather evident, this alone should not lead to their implementation regardless of the social impact they may cause. According to Pastra et al [24], such technological solutions may induce both positive and negative effects on people, while the corresponding analysis should go beyond physical impact (e.g. collision risk) and be extended to include other types and forms of possible effects. However, the existing studies on the social impact of RII-related tools are highly limited, focusing predominantly on the social effects of UAV usage (in contrast to satellite imagery). In relation to the latter aspect, Sandbrook [25] distinguishes four main categories of potential social impacts in relation to drones' usage (studying the case of biodiversity conservation): safety, privacy, psychological well-being, and data security. The first category refers to potential safety benefits to those individuals on the ground in the event of a UAV crash in comparison to larger, manned aircraft [26], the presence of safety mechanisms, and the potential to detect criminal activity [25]. At the same time, Lee et al [27] stress that the absence of a pilot can make UAVs more prone to crashes. From the privacy perspective, the application of drones (as well as other aerial monitoring and image-capturing technologies, including high-resolution satellite imagery) raises various ethical concerns in relation to possible surveillance issues, violation of privacy, human rights, and civil liberties [28]. The psychological well-being of individuals might be enhanced due to empowering local communities by providing access to their own data-gathering tools [29], while UAV applications may provoke fear and confusion among those on the ground [30]. Finally, the usage of drones may raise concerns about how collected data is used, to what extent is it protected and to whom is it shared [25]. The latter aspect is specifically important considering the implementation of AI components in the RII tools (which raises ethical and data privacy considerations) [31].

However, these broad and relevant categories do not consider other possible impacts and specific social groups related to differing purposes of UAV usage, as in the case of CIs setting. This limitation implies the creation of a context-specific set of categories tailored to the RII tool proposed by the SUNRISE project.

III. METHODS

The framework presented in this section aims to evaluate the impact of the project's results and form a sustainability roadmap for their continued existence beyond the project's end. The project requirements imply the identification of the societal impacts of SUNRISE solutions and communication of the corresponding set of recommendations that will help the solutions' adopters (CI operators) to mitigate potential negative impacts and enhance the benefits of the SUNRISE tools, given that foreseen impacts will be evaluated continuously during the project. The section begins with an overview of the overall strategy applied for all the technical solutions of SUNRISE, followed by the ex-ante assessment methodological framework applied, providing an overview of a more detailed explanation of methods used in relation to the social domain in relation to the RII tool.

A. Framework

This section presents a comprehensive strategy for continuous evaluation of the impact produced by SUNRISE toolsets. This approach advocates initiating the evaluation by defining the project scope, outputs, stakeholders involved, and relevance of various impact areas and dimensions. Following this, an impact evaluation process is outlined detailing its strategy, phases, timing, and limitations. Subsequently, the data-gathering process starts, utilizing the methods selected in the previous phase. Once the data is gathered, the analysis ensues and provides a comprehensive report on the findings. Moreover, given the necessity for continuous impact evaluation to ensure the quality of SIA, two additional stages are included in the strategy assessment during tools' testing and monitoring, followed by final reporting. The strategy aims to provide a specific yet versatile set of consecutive and analytical steps, which includes the stages presented in Table 1.

To improve the quality of the assessment, and to incorporate the most applicable assessment practice that focuses on participatory approaches, the present strategy prioritises the project's specifics, considering the solutions characteristics proposed by SUNRISE and their development stages. In this article, the RII tool is presented in detail, presenting the methodology of defining and validating indicator categories for the tool. As the tool is not yet in a testing phase within the CIs, the aim at this stage of the project is to present the progress of the evaluation strategy, represented by the results of identification of the ex-ante impacts and validation of the results by confronting the opinions of the developers and those of the CI representatives.

The following section presents a detailed explanation of the methodological framework applied for social impact evaluation. As the first two stages are highly project-specific and out of the scope of the study, the article focuses on defining and validation of indicators, corresponding to stages 3 and 4 of the General Framework presented in Table I.

B. Defining and validating the SIA indicators (Stage 3)

The key issue of impact evaluation lies in defining the appropriateness of the indicators, such that the coverage of all impacted domains and parameters is ensured. To do so, the authors applied an approach drawing upon the '3S' methodology (self-validation, scientific validation, and social validation) [32], which emphasizes reliance on expert judgments and public participation. However, the adapted methodology has been refined to facilitate a suitable ex-ante assessment, recognizing the critical role of expert knowledge in the early stages of solution development. Public

TABLE I.
SIA'S GENERAL STRATEGY FOR THE SUNRISE PROJECT

Stage	Description
1. Screening and Profiling	Understanding potential issues, gathering secondary data on impact areas, and engaging experts and partners (help to formulate an overall evaluation strategy, establishing a common framework that can be applied to other impact analyses).
2. Scoping	Characterising the technological solution, involving experts and developers (identification of limitations and areas requiring more in-depth evaluation based on participative approaches to create a list of evaluation indicators tailored for each area).
3. Defining and validating impacts	Defining (and selecting) specific indicators and variables within the social area.
4. Verification of indicators and Assessing Foreseen Impacts	Investigating foreseen impacts across the evaluation domains, outlining expected changes ex-ante as perceived by various stakeholders in relation to identified indicators.
5. Interim reporting and Provision of feedback to allow Enhancement and Redesign	Providing feedback to stakeholders about potential benefits and issues related to Tools' deployment and usage (support to improve the toolsets from a social perspective).
6. Assessing impacts and cumulative effects	Investigating direct and associated impacts identified during tools' testing (with the use of both qualitative and quantitative approaches).
7. Monitoring and final reporting	Ensuring the accuracy of the assessment and including the development of the sustainability roadmap.

participation is integrated into later stages of the SIA, once the tool is deployed and tested by additional groups of end-users. Furthermore, expert validation is integrated with ex-ante impact evaluation to streamline the process and ensure more efficient allocation of project resources. This approach minimizes unnecessary data collection steps, crucial in project-based impact assessment contexts where resources are often limited.

The approach is based on two consecutive stages. First, the initial validation phase of defining the indicator categories uses information obtained from a literature review to create an initial set of indicators, which forms a basis for their later refinement. The second validation phase is performed by the assessment team itself to capture social sciences and humanities (SSH) partners' opinions on the set of possible parameters and to refine the initial list of indicators. It is worth noting that there is a necessity to balance the relevance of potential impacts and the inclusivity of indicators.

To perform the identification stage, the authors applied the indicator-based approach presented by Schuck-Zöller et al [33]. This approach implies an 'evaluation cascade', proposing a hierarchical categorisation of indicators, ranging from generalised groups to more precise evaluation units and parameters, containing the following categories: Dimension – Criterion – Indicator – Method. Combined, these categories form a classification framework for the social area.

C. Verifying the SIA indicators and conducting an ex-ante assessment (Stage 4)

Once the initial validation (defining) of indicators is finalised, the expert participant verification stage is applied to reach a consensus on the key impact parameters as well as to ensure transparency in the assessment procedure. This validation stage is needed to ensure the credibility of SIA and to avoid false assumptions that might occur during the initial validation process.

To streamline the evaluation procedure, this phase is combined with data gathering for the assessment process. This stage comprises two consecutive steps: (i) conducting an expert-oriented survey and (ii) carrying out a focus group to provide a better understanding of key issues identified by the survey. The expert stakeholder groups involved in the evaluation process were formed independently for each tool, while the participants were selected based on their expertise in the technical and operational specifications of technological solutions. These expert groups are comprised of tool developers and CI representatives who are directly involved in the tool development and implementation processes and therefore they possess expert knowledge of the solution's components, deployment and operation procedures, which is necessary to conduct an ex-ante evaluation. Finally, the framework's timespan and methods are tailored to align with the toolsets' development phases.

(i) Preparation and conducting a mixed-method survey on foreseen (ex-ante) impact assessment for the tool: this phase is needed to further advance indicators' validation and to identify key impact parameters (by juxtaposing response trends from two aforementioned groups of stakeholders involved in the tool's deployment).

(ii) Carrying out a participatory online focus group for the tool (involving CI representatives, and tool developers) is required to assess the foreseen impact on key Impact Assessment topics based on the survey results. Focus groups are used to gather additional qualitative data by engaging a small group of participants in an open discussion about specific topics. These tools are particularly useful for exploring attitudes, opinions, and perceptions. Besides, focus groups are helpful to generate a range of perspectives, and deeper insights, reveal nuances, and capture a variety of viewpoints by stimulating discussion among participants [34]. SIA practitioners may choose to conduct surveys and focus groups sequentially, using the findings from one phase to inform the design or focus of the subsequent phase. The recordings of the moderated online focus group were transcribed for subsequent analysis of the impact assessment categories.

These steps of defining and verifying the indicators are presented in Figure 1. Carrying out these steps was followed by

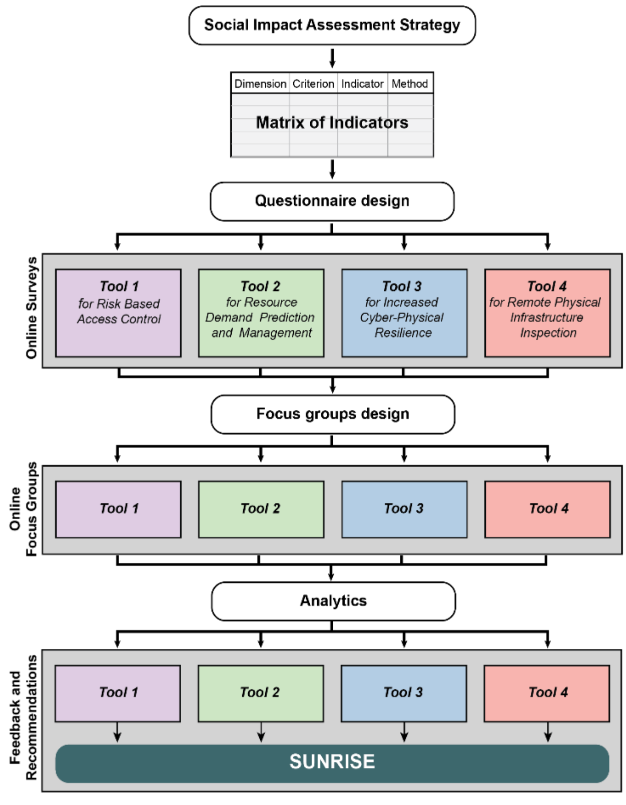

Fig 1. The framework for defining and verifying the SIA indicators for the SUNRISE technical solutions

formulation of feedback to consortium partners to mitigate negative effects and enhance positive impacts.

IV. RESULTS

The following parts present categorised sets of indicators to assess the social impacts of the tools. These sets represent the results of the two phases of the indicator validation framework introduced in the previous section.

A. Defining the indicator categories for the Remote Physical Infrastructure Inspection tool

To initially validate indicators, we utilized an inclusive set of social impact assessment dimensions and criteria based on Rainock et al. [35], adapted into 'Dimensions' and 'Criteria' categories following the framework by Schuck-Zöller et al. [33]. The original set included seven dimensions: Stratification, Employment, Health and well-being, Human rights, Networks and Communication, Experience of conflict and crime, and Cultural Identity and Heritage. During the second phase of indicator verification, it was found that only a limited number of these dimensions directly applied to the RII technical solution. Consequently, the categories of Cultural Identity and Heritage, and Experience of conflict and crime were deemed out of scope to streamline the assessment process. Additionally, the dimension of 'Stratification' was refined to focus specifically on equality-related impacts relevant to the project's scope.

TABLE II.
DIMENSIONS, CRITERIA, AND INDICATORS USED FOR THE SIA OF THE REMOTE INFRASTRUCTURE INSPECTION TOOL

Toolset description		**Ethics, Human Rights and Privacy**		**Equality**	
Toolset deployment details	*Type of End-Users, Type of Disasters mitigated, Type of CI sectors, Countries of planned deployment, Existing Measures*	***Regulation compliance***	*GDPR compliance*	***Social equality***	*Gender, Workgroups, Physical and Health conditions, Spatial inequalities, Temporal inequalities*
Toolset outcomes	Lockdowns: *Effects on Lockdowns Number, Effects on Lockdowns Length* Access to services: *Quality and availability of services, Service continuity, Equitable distribution of services, Affordability of access to services, Service barriers, Service Delivery models, Technology adoption*	***End-User involvement***	*End-users' participation*	***Skills***	*Skills and training, Training requirements and amount*
		Data management	*Personal data processing, Special categories of data, Intrusive methods of Data gathering, Risk of identification of individuals, Non-public data usage, Data Export to non-EU countries, Risk to rights and freedoms, Incidental Findings*		
Employment		**Health and Well-being**		**Decision-Making, Networks and Communication**	
Work environment	*Change in Work Environment, Absenteeism rate*	***Safety and Security***	*Safety incidents, Security incidents, Emergency response, Long-Term dynamic, Risk-Mitigation Strategies, Technological Testing and Validation Evaluation, False alarms, Recovery Time and Cost, Correction Actions, Public Health Interventions, Infrastructure Security, Emergency planning*	***Communication practices***	*Information flows and information dissemination, User Awareness regarding features, Accessibility and Inclusivity, Scope and extent, Frequency and timeliness, Two-way communication, Collaboration and Knowledge Sharing, Usability and User Experience, Prediction information sharing within the CI, Prediction information sharing with stakeholders, Transparency with stakeholders, Information sharing with customers, User Engagement, Inspection information sharing within the CI, Inspection information sharing with stakeholders*
Work-life balance	*Change in Work-Life Balance, Autonomy, Flexibility, Working remotely*	***Health (Mental health, Physical health, Health risks)***	Mental health: *Stress and Anxiety, Social Isolation and Loneliness, Sleep Quality, Emotional Well-being at workplace, Cognitive Load and focus, Tool Dependency, End-user behaviour*	***Interpersonal relations***	*Frequency, Relationship strength, Community building, Networking opportunities, Inclusivity, Belonging, Conflicts*
Working hours	*Change in Working Hours, Working time, Workload, Working outside office hours, Efficiency at work*		Physical health: *Physical Activities, Sedentary behaviour, Infection prevention at workplace* Health risks: *Adverse Health Effects, Injury rates, Emergency response mechanisms, Exposure to Health risks for end-users, Healthcare goods distribution, Access to Healthcare services, Health risks for CI customers*	***Decision-making and Management***	*User Empowerment, Distribution of decision-making authority, Prioritisation of user/customer needs, Collaboration and co-creation, Delegation of management tasks, Decision-making transparency, User-initiated actions, Distribution of management responsibilities, Management during peak demand periods, Policy development*

The outcomes of the two initial validation stages are presented in Table II, listing indicators linked to dimensions and impact criteria for assessing the RII tool's social performance. It includes specific dimensions and corresponding Criteria that evaluate potential positive and negative impacts on diverse social groups. Through the indicator-definition process, five key dimensions of social impact were identified: 'Ethics, Human Rights and Privacy', 'Equality', 'Employment', 'Health and Well-Being' and 'Decision-Making, Networks, and Communication'. Additionally, a general 'Tool Description' dimension was necessary to account for the toolset parameters and deployment factors that can significantly affect the social domain.

B. Verifying the SIA indicators for the Remote Infrastructure Inspection tool

The analysis of ex-ante impacts in relation to the implementation and usage of the RII tool aims to provide an evaluation of the potential future effects of the deployment and usage of the tool. In the first phase, eight survey contributions were collected, including five respondents involved in the tool development and three representatives of CIs (transport sector, water and energy supply sectors). In the second stage, the focus group was conducted, involving twelve participants, including representatives from five CIs concerned with the RII tool deployment (transport sector, telecommunication sector, water and energy supply sectors). The focus group structure was aligned with the 'Dimension' parameter of the list of evaluation indicators presented in Table II, covering all the dimensions identified in the 'Defining and verifying' stage.

The following sub-sections present four key impact categories identified during the validation and verification procedures of SIA, namely awareness of pre-existing infrastructure inspection solutions, data collection and management, work satisfaction, and safety.

Awareness of pre-existing infrastructure inspection solutions

Tool developers had difficulty answering whether there were pre-existing measures prior to tool application, while only CI operators were able to confirm the existence of prior solutions. Focus group participants from tool development partners confirmed their limited awareness of the pre-existing solutions. At the same time, a focus group member from a CI highlighted that not all the developers are aware of the existing measures in CIs.

Data collection and management

The operational functioning of the inspection toolset involves potentially intrusive methods of data collection and processing, including various satellite imagery modalities (optical, multispectral, etc.) and the use of UAVs equipped with different visual sensors (optical, multispectral, etc.). According to survey contributions, there will be no intentional recording of people. However, since certain infrastructures in areas frequented by citizens may be recorded, it is the responsibility of tool operators to pixelate any potentially identifying elements in the footage. Thus, according to survey results, there will be no risk of identifying individuals. Regarding anonymization practices, Tool developers confirmed that they are only needed for UAVs (in contrast to satellites, where such practices are not needed), and they might be advanced beyond face pixelization. Regarding the anonymization procedure, a CI representative described it as a straightforward task, but clarification of the procedure is needed. Another concern expressed during the focus group refers to the decrease of the toolset's functionality due to the excessive anonymisation techniques applied (as in case of over-blurring), which may increase false positives by blocking significant parts of the images provided by UAVs. According to a CI representative, a potential solution to this issue might be represented by the application of the tool model prior to the anonymisation of the images.

Work environment

Although most survey respondents foresee no changes in the Work Environment, three participants noted potential impacts. They anticipate improved employee satisfaction due to safer remote work conditions and fewer on-site inspections. This could also reduce absenteeism by around fifteen to twenty per cent, as discussed in focus groups, primarily attributed to enhanced safety and risk minimisation.".

Additionally, changes in employees' working hours may occur due to seasonal adjustments and reduced work hours with maintained financial compensation. Respondents anticipate reduced working hours and lighter workloads, alongside increased efficiency. This trend was supported in focus groups, emphasizing improved efficiency and inspection processes through detailed infrastructure information, minimizing unnecessary on-site visits and equipment requirements. Current inspection practices often involve regular visits regardless of immediate issues, whereas future approaches may prioritize visits only during operational failures.

Survey respondents indicate a mixed impact on employee job satisfaction. Positive changes include Increased Engagement, Improved Work-Life Balance, Enhanced Recognition, Career Advancement Opportunities, Meaningful Job Responsibilities, Positive Team Dynamics, Supportive Leadership, and Job Security. Conversely, potential negative impacts noted are Unrealistic Expectations, Increased Workload, Lack of Recognition, and Ineffective Leadership. Focus group discussions confirmed these trends, highlighting both positive and negative aspects. For instance, there were concerns about unrealistic expectations related to satellite image capabilities and optimism regarding improved recognition and employee well-being.

Safety and security

According to the major trend of the verification stage responses, the contributors foresee a positive impact on the safety and security of the end users, which includes decreasing in the number of workspace safety and infrastructure security incidents, as well as an increase in emergency response efficiency. At the same time, the verification stage is indicative of the positive foreseen impact that can be identified in the number of false alarms. Besides, the development team representatives marked the high level of dependency of the number of false alarms on the CIs' preferences, as some of the infrastructures prioritise the detection of any kind of changes, while the other CIs are interested in the detection of only a certain type of changes.

The focus group identified differing opinions regarding the number of security incident detections. CI representatives suggested there might be a decrease in the number of detections due to earlier problem identification, whereas tool developers argued that the number of incident detections might increase due to more frequent checks that would lead to a reduction in the number of security incidents. However, all the participants unanimously agreed that a positive trend in infrastructure security will prevail.

Concerning the efficiency of the Emergency response procedures, the focus group participants highlight the increase in speed of feedback and reaction time, as the tool implies real-time updates of the required information.

V. DISCUSSION

This section reviews the results of the two initial ex-ante evaluation procedures outlined in this paper, namely defining and validating indicators (Stage 3 of Table I) and verifying indicators' categories (Stage 4 of Table I). These procedures establish the initial framework stage of impact areas' definition and evaluation, forming a basis for the following stages of continuous SIA of the project.

A. Defining and validating the indicators (Stage 3)

In the stage of defining categories and specific impacts, six inclusive impact dimensions were identified: Toolset description; Ethics, Human rights and Privacy; Equality; Employment; Health and Wellbeing; and Decision-making, Networks and Communication. While some of these dimensions are expected for SIA of the RII solutions (e.g. ethics concerns, health-related consequences), other dimensions of possible impacts are not commonly present in SIA literature of the RII technological tools (e.g. effects on decision-making and employment) [25-28]. The assessment of the impact dimensions identified is not consecutive, however, the inclusion of the 'Toolset description' dimension as the initial (introductory) step is deemed necessary as it informs the tool deployment specificities and possible outcomes of its implementation. Accordingly, this dimension allows contextualizing the tool deployment setting and the definition of its end-user groups, which facilitates subsequent impact evaluation.

As it follows from the literature devoted to SIA of the RII-related technologies, the dimension of ethics, human rights and privacy raises numerous concerns [25]. The present methodology facilitates the structuring of this dimension in relation to regulation compliance, data management practices and end-user involvement in the tool development and deployment processes, as these criteria were identified as both relevant and inclusive for the context of the RII tool.

According to existing impact assessment literature, the dimension of equality is essential to the SIA of technological solutions [36], however, given a broad range of possible social groups affected by a technological solution, the list of specific categories, containing related indicators is highly context-dependent and needs to be verified carefully. The defining and validation stage of the proposed methodology identified the relevance of the 'social equality' and 'skills equality' categories for the RII solution of SUNRISE, allowing us to consider the possible impact on equality for different employees groups and CIs customers.

As CI employees are perceived as the primary end users of the toolset, the employment dimension is crucial for the current SIA. Existing literature emphasizes its significance [37,38], but empirical evidence on the impacts of technological tools on employment is limited [39]. In the RII context, our methodology identified Work environment, Work-life balance and Working hours as key criteria for assessment. The adoption of new technology in daily operations directly affects how people work, including the types and volume of tasks. Our ex-ante SIA findings underscore the increased importance of employees' efficiency for CIs representatives (due to technology implementation), potentially leading to greater job complexity [40]. Moreover, the introduction of new technologies may promote a skill-biased shift within organisations, benefiting skilled employees [41]. Consequently, this shift may raise expectations for higher performance among employees, as tasks supported by new tools could be perceived as less time- and effort-demanding compared to the traditional work settings.

The dimension of Health and well-being is covered in the SIA of technological solutions [42]. However, the list of possible health-related impacts and thus indicator categories to include in the assessment significantly depends on the social groups affected by the implementation of a specific tool [43]. Accordingly, the initial selection of categories for the current impact evaluation was preceded by the identification of social groups affected and end-users of the RII solution. The methodology allowed the assessment team to identify Safety and security, and Health criteria (including sub-criteria of mental, physical, and health risks) as the relevant categories. Such an approach considers a wide range of impacts on individual, group and organisational levels.

Networks and communication are often present in the SIA frameworks, however, the usual focal point of the studies concerning these aspects is communication technologies [35]. At the same time, the impact of technological solutions on decision-making is well-studied in management-related literature [44]. Considering the importance of CI employees as the social group directly affected by the RII tool deployment (as well as the potential change in the everyday work scenarios), the dimension of decision-making, networks and communication is deemed necessary for inclusion in the list of indicators of SIA of the RII tool (Table II). Indeed, communication and networking between employees might be directly or indirectly affected by the implementation of new instruments as they change the work environment, e.g. from on-site to remote inspection. The impact-defining stage results indicate that new ways of obtaining inspection data may have repercussions for the division of responsibilities between employees (or groups of employees) and the decision-making process within a CI.

This inclusive set of dimensions (containing related criteria and specific indicators) forms a basis for the following verification procedure, aiming to identify and evaluate the key impact categories concerning the RII solution implementation.

B. Verification of indicators and conducting Ex-Ante Assessment (Stage 4)

The impact category of Awareness of pre-existing infrastructure inspection solutions refers to the knowledge of specific CI settings among tool developers. The results of the impact verification stage highlight the need for increasing awareness regarding this parameter within the development team. The lack of such awareness may lead to inconsistencies in the development and deployment phases, which in turn may instigate negative outcomes for CI organizations, their employees, and customers. The high level of importance of contextual and procedural information for the consortium partners conditions the inclusion of the 'Tool description' dimension in SIA, especially in a project-based context, where tool deployment settings may vary significantly. Otherwise, highly prominent peculiarities of tool development and implementation might be omitted. Therefore, considering this aspect in the SIA framework enables the provision of valuable feedback to tool developers.

Another impact category that was identified as specifically important for the RII tool refers to data collection and management. Indeed, the wider dimension of ethics and privacy is highly relevant to the social impacts of technological solutions [45] as well as RII-related tools [25]. However, it is necessary to define what types of ethics- and privacy-related impacts are the most relevant for specific use cases and modules (components) of technological solutions. Arguably, one of the possible solutions to this task is the engagement of groups of experts who are actively involved in tool development and implementation as they possess knowledge concerning the specific context of tool deployment. In the case of RII of SUNRISE, these groups are represented by tool development partners and CIs representatives, as the proposed solution contains multiple components and tool implementation settings vary by infrastructure sector and location. In this regard, the results of impact verification indicated that ethics and privacy-related concerns were specifically relevant for UAV usage in comparison to satellite imagery due to the technical specificity of each module. Among those concerns 'Data collection and management' criterion was identified as the key impact parameter of the dimension of Ethics, Human rights and Privacy. The verification process during the focus group highlighted possible issues and ambiguities concerning data collection and management, namely potentially intrusive methods of data collection and anonymisation procedures. Besides, direct communication between tool developers and CIs representatives during the focus group discussion allowed clarification of data collection and management practices and formulation of possible solutions to maintain tool functionality while applying privacy-related procedures.

The criterion of work environment is rather well studied in SIA literature on technological solutions [46]. However, in the case of the RII tools the existing research on this criterion is limited, thus it may be easily omitted in case the impact category list is based solely on practitioners' perspectives. This claim bears even higher prominence for the impact categories that constitute this criterion, as technical tools for remote inspection differ significantly, and hence their planned and unplanned impacts on the work environment are also highly varying. In the context of the RII tool of SUNRISE, the stage of indicator verification allowed the impact assessment team to highlight two key dimensions of possible impacts: absenteeism rate, and workload changes. Besides, a possible connection was identified between these aspects and the job satisfaction rate of the CI employees. This link is also confirmed by academic literature, as the change of workload to less physically demanding tasks may result in an increase in the satisfaction level among workers [47]. At the same time, a higher level of employee satisfaction with their jobs and work environment may lead to a decrease in the level of absenteeism [48].

Finally, the indicator verification stage indicated the relevance of the 'Safety and security' criterion for both developers and CIs representatives. As follows from the literature review, the notion of safety is rather well-considered in relation to UAV usage [25],[30]. However, the present impact verification methodology highlighted another attribute of this parameter: in contrast to the mentioned research, the focus of the application of drones is compared to the pre-existing setting of inspection, but not to other ways of conducting aerial vehicles or safety in case of a crash. This allowed the identification of potential context-specific safety implications, relevant to the implementation of RII in CIs, in particular, the change of employee's work tasks from on-site to remote inspection is expected to increase the level of safety. Besides, impacts on emergency response and number of false alarms were identified as highly relevant for focus group participants. Arguably, these security-related impacts are deemed prominent due to the specific context of CIs as the tool deployment setting.

C. Ex-ante SIA framework overview

The SIA frameworks are increasingly valuable for project practitioners responsible for the evaluation of a spectrum of social phenomena impacted by technological solutions. However, existing frameworks provide rather narrow empirical evidence for procedures of defining and verifying the categories of social impacts [34], where the results are frequently grounded in the practitioners' or authors' perceptions [1]. As a result, the frameworks outlining several categories of impacts are characterized by a significant level of inconsistency between such impact categories (ibid).

To mitigate such inconsistency, the authors propose focusing on the methodological phases of ex-ante assessment for defining and verifying indicators, rather than the formulation of a ready-to-apply list of indicator categories. This approach ensures that both the tool specificity and the broader context of its development and implementation are taken into account.

The proposed methodological framework allows the collection of the expert perspectives (e.g. CI representatives, tool developers, SSH experts) on the social impacts of the specific tool, as well as identifying the key impact areas, thus avoiding grounding the impact assessment criteria solely on the impact evaluation practitioners' beliefs and perceptions. This is done through collection and structuring of the broad and inclusive range of social impacts at the initial stage of indicator definition and validation, allowing to contextualise the list of potential impacts both in terms of the project (e.g. end-users, tool deployment) and specific technological solutions adapted to contain an inclusive list of relevant impact dimensions, criteria and indicators. Subsequently, this range of indicators is verified by conducting successively an expert survey and a focus group, highlighting the key areas where the most prominent social impacts are expected.

Such an approach is tailored to consider the technical specifications of targeted solutions, resulting in enhanced relevance and granularity of the SIA procedure and results. This enables comprehensive impact analysis, where a high level of method adaptability allows for the inclusion of specific indicators that are most relevant to the technology, required to enable more meaningful impact assessments [2]. Besides, expert stakeholder engagement in the ex-ante evaluation allows for specific risk identification and targeted mitigation measures before solution deployment.

Concerning the project-based context of SIA, the proposed methodology proposes a solution to enhance resource allocation during the SIA process by combining methods for indicators' defining and verifying stages, which enables cost savings while ensuring the identification and analysis of critical aspects. The adjustment of resource allocation is often prompted by the context of a project, where impact assessment needs to consider tool development and deployment phases as well as material resources' limitations [23].

At the same time, several limitations of such an approach need to be highlighted. First, the current research presents the application of the adaptable methodology tailored to a specific technological solution, thus if applied to other tools it requires to be adjusted in accordance with other projects' aims and technological specifications to ensure the relevance of the SIA results. Similarly, if applied in a different setting, the approach needs to be adapted to specific project requirements (e.g. development stages, timeframes, resources, etc.) and deployment context (e.g. location, stakeholders, etc.). At the same time, modifying the methodology for different projects or technologies can be complex, resource- and time-consuming. The latter aspect includes the requirement of an extensive analysis of relevant theoretical sources and empirical evidence to establish an inclusive yet relevant list of impact assessment indicators as well as a possible requirement to conduct specialized training to apply the tailored methodology, which may incur additional costs. Moreover, as technologies evolve rapidly (and tend to include additional components) [49], a tailored methodology may quickly become outdated, requiring frequent updates to remain relevant (e.g. to include additional impact categories). Therefore, more empirical evidence of the application of the proposed ex-ante approach to other tools and settings is needed to inform the level of applicability and transferability of such a methodology.

Concerning the context of the SUNRISE project, the presented ex-ante methodology represents the first iteration of the SIA framework, aimed at analysing potential impacts on the development stage of the solutions. Therefore, as the presented approach is part of an ongoing SIA, where only the first round of assessment (ex-ante analysis) is completed, the overall results of the evaluation are not yet available. The findings from the initial phase of impact assessment lay the foundation for the next phases of the evaluation process: the subsequent assessment phase will occur following the pilot implementation of solutions, employing a mixed-method approach that focuses on the implications of toolset implementation for end-users. Due to time constraints, for the moment, only a limited number of focus groups were conducted, while additional focus groups, semi-structured interviews and surveys (engaging other stakeholder groups) are planned to be carried out at the subsequent stages of iterative SIA.

VI. Conclusion

This article outlines the rationale, strategy, and methodological phases of the ex-ante impact assessment, focusing on its application to the RII solution within the SUNRISE project. The evaluation strategy is designed to conduct an iterative social impact assessment of the technological solutions throughout the project's lifecycle. The ex-ante approach presented addresses the need for a standardized framework, facilitating a comprehensive understanding of potential social impacts and allowing for adjustments based on stakeholder input before deployment.

The article details the initial phase of a social impact assessment strategy, involving the definition and verification of impact categories specific to the RII solution. It begins with establishing a robust set of indicators and employs a participatory verification approach to identify critical subcategories of social impact. These phases aim to enhance understanding of the technological context, provide valuable feedback to developers, and optimize resource allocation for project-based social impact assessments prior to implementation.

Acknowledgment

This research has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101073821 (SUNRISE).

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