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Stakeholder-Driven Consequence Modeling Employing Cross-Impact Balance Scenario Analysis

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ABSTRACT

Future research, including participatory research, can help to explore stakeholder perspectives. This capability is observable in scenario methods such as the cross-impact balance analysis that aggregates factors from which scenarios and further research opportunities are derivable. In this methodologically oriented paper, a modeling idea is explored, in which consequences are considered as flexible factors in the modeling process, rather than drawing on fixed impact-consequence linkages. The study proposes an extension that explicitly models implicitly acting consequences to increase stakeholder involvement and system understanding. In this regard, the manuscript argues that this approach enables reflection on the modeling and potential results during this process, as they are constructed around these consequences or, more generally, system indicators. Thus, this approach provides an opportunity to integrate cross-impact assessment more effectively into stakeholder dialog by facilitating the tracking and discussion of structures. The study also illustrates the methodological approach by highlighting its application to the topic of water governance. In addition to the potential for utilizing this approach in workshops and participatory co-modeling, the most significant initial finding of this study is that the explication of consequences could serve as a suitable foundation for further studies focusing on stakeholder involvement or impact analysis.

1 | Introduction

Scientifically exploring the future can assist in developing knowledge about upcoming problems (Bell 2003) and, in many cases, also inform about potential impacts (Van Woensel 2020). However, in the context of wicked problems, there might be limitations to what is achievable. This is because wicked problems are characterized by their ability to involve multiple actors, as well as their high level of interconnectedness (Head 2022). One of the best-known wicked problems is climate change, which affects everyone to varying degrees. These issues can vary in terms of complexity, but at their core, they concern elements that are not easily comprehensible, interconnected, and potentially subject to significant future change. Highly adaptable models can also be valuable in the context of participatory modeling, which has become a popular approach (McGookin et al. 2021; Singh et al. 2021), particularly given that the issues that such models investigate can often affect several individuals or groups (Basco-Carrera et al. 2017; Hare et al. 2003; Röckmann et al. 2012). In addition, even methods that have already been used and assisted in settings with stakeholders (Kosow et al. 2022; Tori et al. 2023) may have the potential to be even further expanded or adapted for other applications.

The focus of this study is also to look at participation because even if there are the aforementioned difficulties in future research, an important aspect of value is to involve the people who will be part of the future being researched (Hinrichs and Johnston 2020; Vaughn and Jacquez 2020). When considering

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future-related modeling and especially participatory modeling, the concept of visioneering (Sand and Schneider 2017) comes to mind. This concept of visioneering alludes to the notion that, through the involvement of individuals in futures studies, specific visions of the future can be shaped and "engineered" (Bajde et al. 2022; McCray 2017). However, if this idea of visioneering is followed unreflectively, the process could result in either overly vague outcomes (scenarios) or an overly functionalist approach to "engineering visions." To mitigate such results, the use of participatory scenario-building techniques may prove beneficial. However, what could be done to make such modeling work more inclusive or demonstrative? This text proposes an extension of the cross-impact balance (CIB) method to address this question.

The CIB method is a systematic approach used to construct qualitative and semi-quantitative scenarios. CIB evaluates the interrelationships between various factors in a system by using a cross-impact matrix and an evaluation algorithm (Weimer-Jehle 2006). A CIB matrix consists of multiple descriptors, each of which includes variants. These variants can exert either a promoting or hindering (numerical) influence on the variants of other descriptors within the matrix. This method is particularly useful for analyzing complex systems where qualitative knowledge plays a significant role (Weimer-Jehle 2023). The proposed extension to the CIB framework involves the integration of (consequences) indicators. These indicators are modeled alongside other descriptors in the matrix as specific consequence descriptors. However, they are distinct in that they serve exclusively as passive elements, without any actively influencing variants. Thus, these consequence indicator descriptors can only exert implicit influence within the model. The term "implicit" here means that the consequences indicator descriptors do not actively affect other descriptors or directly alter their interactions. Nevertheless, there is a possibility that they may influence the perceptions of individuals involved in the modeling process, such as stakeholders observing these consequences. A primary objective of incorporating consequences as descriptors is to enhance the visual and intuitive interpretation of the system's behavior, particularly during stakeholder engagements. In a CIB matrix, the numerical interdependencies can appear somewhat abstract. Therefore, it may be beneficial to provide a detailed explanation of the results and consequences of the scenarios to facilitate understanding. Here, the aim is to enhance the exchange between stakeholders and researchers while also improving communication among stakeholders themselves through these indicators. The presence of such indicators can also facilitate the assessment of specific shifts within the system, thereby enabling the testing of various strategies that could assist decision-makers.

In this context, scenario-based and stakeholder-involving methods appear to be a promising approach (Duinker and Greig 2007), particularly if they are transparent or adaptable (Carlsen et al. 2017). The inclusion of specified consequences in CIB modeling can be a convincing approach, as such an inclusion has not been the primary focus of the method so far. Furthermore, this modeling approach especially aims to strengthen research approaches with CIB that want to focus more on potential consequences. For CIB, which is a systemic scenario analysis focused on presenting a structure of potential interactions of variants (Weimer-Jehle 2006), the addition of explicitly displayed consequences that are a result of the interactions promises new opportunities. To provide an applied example alongside the methodological presentation, a demonstration application on the topic of water conflicts is presented in addition. This example is derived from a study focusing on Germany, observing the country's water resources and possible future impacts, including conflict. In this context, there have already been indications that water conflicts are highly interconnected and that structured approaches are needed (Brauner 2024; Hasan et al. 2025; Kåresdotter et al. 2025). Nevertheless, this example is mainly intended to demonstrate the fundamental ideas of this modeling approach, which can be applied to a variety of other subjects.

Starting from the idea of shaping visions, we will introduce the consequence indicator approach to the CIB analysis (Weimer-Jehle 2006, 2008). This approach could have the potential to elevate both the work of researchers (e.g., the internal modeling process) and that of involved participants, such as stakeholders or experts. The inspiration for this CIB modeling approach stems from the need in an associated project to improve the demonstration of the impacts of alternative variants, particularly because of potential stakeholder collaboration or participatory modeling. Thus, the purpose of this paper is to describe the new methodological approach in question and assess future possibilities. Accordingly, we want to address the following questions: In what ways does this approach broaden the scope of CIB modeling? What possibilities does this approach create for participatory modeling?

The following sections firstly offer an introductory literature review on the topic of consequences in futures studies and an overview of the CIB method. Secondly, the methodological approach outlines the typical usage of CIB, with a specific focus on the proposed addition to this method. Thirdly, an illustrative example and initial results from stakeholder exchanges are provided to further assess the new approach. The paper concludes with a critical discussion of this new approach and its potential applications, before offering a summarizing conclusion.

2 | The Focus on Consequences in Futures Studies – A Brief Literature Review

The significance of consequence is evident in the increasing number of future studies, especially those focused on climate change (Delpla et al. 2009; Hellmann et al. 2008; Herman and Treverton 2009; McCarty 2002; Thuiller et al. 2011). Because the basic premise of such research is generally to ask what we (as humans) could do (now) to achieve a certain result or outcome. Such research can include studies on emergency preparedness (Bañuls et al. 2013) and the conditions necessary for future events (Ekholm and Schaber 2025). In other words, futures studies explore the future to show consequences that may be desirable or undesirable. For this manuscript, we use the term consequence to refer to both intended and unintended consequences, their direct or indirect effects, and the mentioned desirability. Although many intended actions can have unintended consequences (Merton 1936), especially as the future is not certain. However, this trait also makes the field

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relevant because it allows for the consideration of yet unforeseen or unexplored factors associated with future impacts or actions. After all, there may be underlying structures that could be uncovered, thus yielding insights into the otherwise unknown future. Given the pivotal role of policy makers in shaping the future, policy or impact assessment (Adelle and Weiland 2012) represents a systematic approach to analyzing the consequences, or in this case, impacts, of projected policies. In the best-case scenario, such research can prevent future conflict, even if future research may entail some uncertainty. Any extension of the CIB method, in this case with the focus on consequences, can change the way the modeling is approached, even if only to a small extent. Thus, even minimal changes in the modeling framework may induce shifts in the dynamics of stakeholder engagement. Such a reflection can also be seen in the notion of visioneering, which is a term describing the potential engineering of visions (and thus influencing the future) through researching about the future and future consequences (Sand 2018). The concept of visioneering (McCray 2017; Sand 2018) emerged in the field of vision assessment, which in turn has its origins in technology assessment (Grin and Grunwald 2000). The practice of technology assessment has gained considerable traction in recent decades, both within the realm of academic research and among policymakers and industry leaders (Grunwald 2018; Lösch et al. 2019). This traction is largely due to the growing demand for assessing future trends, particularly in the area of technology, to identify potential developments and assess the potential chances or consequences (in all its variations) of technologies, including their societal impacts (Lösch et al. 2019). Examples of technologies encompass studies on smart grids, lab-cultured meat (Ferrari and Lösch 2017) or artificial intelligence (Alami et al. 2020), which could inform subsequent developments of these technologies. In addition, some approaches also aim to understand past technology discussions, such as the discourse surrounding a chemical pesticide, showing that the production of risk knowledge is complex and often involves a search for consequences (Böschen 2002).

Besides this interest in the consequences identified in the literature, for the study, there was a more important reason for this adaptation. As suggested by research on modeling, specifically modeling with stakeholders or participatory modeling, there are benefits in refining current models that already have most of the tools needed for the research at hand (Gaddis et al. 2010; Voinov and Bousquet 2010; Voinov et al. 2016). Even the literature about the CIB analysis has cited such recommendations for enhancement (Lazurko et al. 2023; Tori et al. 2023), which we will present in the following. A big factor for modeling, thinking about the powerful yet sometimes incomprehensible models as seen in climate change research, is transparency (Robertson 2020; Skea et al. 2021). It could be argued that a lack of transparency in a model could negatively affect its effectiveness in terms of public outreach, potentially leading to distrust, as currently seen with discussions on AI (Dwork and Minow 2022). Meanwhile, analysis shows that transparency can increase public trust in the government (Wang and Guan 2023). Therefore, if one wants to work more on a bottom-up level, involving stakeholders or even general participants who are not familiar with the topic, such as in student courses, refining the approach might be helpful. Adjustments could enhance efficiency in terms of time and scope while also improving transparency, leading to a better understanding of the studied case (Olazabal et al. 2018). Here, methods like the CIB offer some possibilities in its toolkit to be comprehensible, as all the included factors and interactions can be quickly retraced in the matrix (Weimer-Jehle 2006). Nevertheless, the established framework, which features factors that either promote or impede each other, is flexible enough to allow for adaptations, such as the role of the factors. Given our focus on consequence modeling, this adaptation seems an appropriate addition to this model, as it would not only have the interacting factors from which interpretations can be derived but also direct consequences that can be discussed. In this context of transparency, the proposed approach aims to use the consequence indicator descriptors to improve understanding of the system by providing clear directions for the descriptors and their effects. Incorporating this addition and recommending extended stakeholder involvement in the process aims to foster transparency and understanding of the model in question. Thus, as suggested in the literature, the aim is to encourage engagement (Sciulli and Adhariani 2023) and decision-making (Bhatt 2024; European Commission: Joint Research, C 2023).

As seen in the literature review, the adaptation of current models in the direction of transparency or participation is important. Here, too, it seems to help to think about integrating consequences in the modeling process. In the context of this study, we decided in favor of the CIB method, because CIB is a flexible method (Weimer-Jehle 2006) and also refers to consequences that are fundamental to the system logic. However, to our knowledge, they have never been explicated to this extent before. CIB is an inherently transparent and qualitative scenario methodology that uses a matrix in which variables are numerically interdependent. A CIB model is transparent insofar as each of these dependencies is re-traceable in the matrix (Kurniawan et al. 2022; Weimer-Jehle 2006). The accompanying software even has dedicated text fields to note the reasons for the values given (Weimer-Jehle 2024b). Furthermore, CIB is qualitative in that the variables are often descriptive (nominal or ordinal) states rather than numerical (metric), even though a CIB with quantitatively defined variables would be possible. Although technically transparent and easily retraceable, a large matrix with multiple influence values may still be perceived as complex. Therefore, the approach emphasizes consequences to provide clearer indicators of the system's behavior, as previously discussed. The flexibility of the approach is demonstrated by the ability to choose such methods to have the matrix for the appropriate context. Published adaptations include the integration of multiple matrices in combined methodologies (Schweizer and Kurniawan 2016) to external and interconnected approaches (Prehofer et al. 2021). Some approaches utilize CIB as a scenario generator to evaluate external indicators, integrating them into mathematical models (Kopfmüller et al. 2021; Pregger et al. 2020), to map dynamic trends (Vögele et al. 2019) or for assessing stable states (Jodlbauer et al. 2022) or metastable (stable under small disturbance) states (Kemp-Benedict et al. 2019). Another study for risk management proposes a probabilistic cross-impact approach to better quantify uncertainties (Salo et al. 2022), while also concepts to improve visualization exist (Schweizer et al. 2023). However, in our approach, we modeled the

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indicators directly into the matrix, while the influence of these descriptors is implicit (no direct influences on the system) and focuses on potential effects on the stakeholders. CIB can be a good and simple way of representing a complex system for the broad view of a particular problem. Furthermore, the objective is not to guarantee an exact replication of reality but rather to emphasize the importance of quality in the process of establishing relationships between different factors and arriving at a coherent conclusion. CIB employs systems theory to construct scenarios predicated upon the interaction of diverse factors, which are supported both qualitatively and quantitatively (Weimer-Jehle 2006; Weimer-Jehle et al. 2016). The initial application of CIB in the field of forecasting has led to its utilization in a diverse range of subjects. These include a heightened focus on issues such as water (Kosow et al. 2024, 2022) and climate change (Schweizer 2020), as well as studies on mobility concepts (Fadel et al. 2024; Tori et al. 2023), health issues (Stankov et al. 2021), risk assessment (Salo et al. 2022), and numerous other topics. A compendium of numerous CIB studies is also available for reference on a designated website (Weimer-Jehle 2024a). The involvement of stakeholders is also at the forefront, especially when problems have not yet been investigated in a system context. Here, CIB helps to highlight possible problem areas and solution spaces, which are then of interest for further research. In the context of water issues and river basins in particular, a study on a similar topic demonstrated the potential of CIB to provide a “bigger picture” (Lazurko et al. 2023). The findings of this literature review, in conjunction with the study's objective, led to the conceptualization of the methodological extension that is outlined in this text. The CIB literature also showed that modeling cases with stakeholders could take a lot of time, especially to understand everything in a system. This discovery also led to the idea of making the consequences of the descriptor interactions more explicit, so that understanding these interactions in the system is more accessible. Another study that goes in a similar direction with stakeholder involvement is from Tori et al. (2023), which graphically represented the results of the CIB to facilitate subsequent discussions. Other studies present various methods for obtaining information for the CIB matrix, ranging from preliminary loop diagrams (Stankov et al. 2021) to CIB-specific approaches (Panula-Ontto and Piirainen 2018), as alternatives to conventional literature reviews or interviews. Additionally, the study considers the potential and effort of stakeholders, suggesting that further research could explore new ways to engage participants or ideas to simplify CIB representation. However, there appears to be a lack of systematic participation in the construction of the CIB matrix. To address this gap, we propose a new approach that incorporates both the concept of providing a “bigger picture” and the facilitation of discussion.

3 | Methodological Approach

3.1 | CIB and the Consequence Addition

In this section, we will first briefly describe the CIB method to contextualize our new approach and recommend the following publications by Weimer-Jehle for further insights on this method (Weimer-Jehle 2006, 2009), as well as a handbook for assistance in practical application (Weimer-Jehle 2023). CIB is a semi-quantitative method for structuring qualitative and quantitative information so that they can be used for subsequent scenario development and analysis. The core of this methodology is the CIB matrix, which is constructed from the data for the case study at hand. This matrix can build on qualitative and quantitative research, or frequently a combination of these, including insights from additional studies, documents, and interviews. However, depending on the research question, objective, and application of specific information, the prioritization of data selection may vary. For instance, the creation of the matrix could commence with stakeholder interviews and subsequently be finalized through further studies, or vice versa. The matrix consists of descriptors (or agents in our case), which can have several variants (or actions in our case). It is possible to model every variant of one descriptor in such a way that they promote or inhibit the variant of another descriptor. The range of values for these influence ratings is from +3 to −3, with 0 indicating no influence. Once the matrix is complete, the matrix can be used for the exploration of the different scenarios by analyzing the different variants that form the scenarios. In the usual case, the method and the associated software identify the most consistent scenarios (scenarios with the highest cross-promoting influences) out of sometimes millions of possible scenarios. This screening of scenarios takes a long time and is almost impossible without computational help. Nevertheless, the calculations can be performed manually, particularly for small matrices, which is a crucial argument in favor of this method's transparency.

Building on this method, we would like to present the new approach of consequence indicators, using figures for additional illustration. The important step, as opposed to a typical CIB, is to extend the matrix with certain result variables that are passive indicators. These consequence indicators resemble descriptors, yet there is a key distinction: The descriptors influence each other and the consequences, while consequences do not influence other descriptors. This approach originates from the aim of integrating consequences as a central component within the CIB methodology, wherein they are subject to influence from other contributing factors. For instance, on a simple level, one consequence descriptor could have two states: (A) The consequences occurred, or (B) The consequence did not occur, e.g., there is water pollution or there is not. However, the idea is to model this consequence descriptor to be even more detailed, as sub-levels are possible, such as (A) slight pollution, (B) moderate pollution, and (C) strong pollution. Furthermore, the possibility exists to assign multiple potential consequences (as a variant) to one descriptor. This prospect is where the method's openness to flexibility and its capacity to incorporate a range of perspectives, including those of different stakeholders, becomes evident.

3.2 | Explaining the New Approach

The objective is to design a hybrid CIB that can be utilized in workshops with stakeholders, both individually and in groups. We suggest that going into the modeling process already reflecting possible consequences can create a space (infrastructure) that could also aid an ongoing visioneering process. In this way, stakeholders' visions of potential futures or

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consequences are combined with the structured approach of the CIB to make these visions more tangible. This structure may also improve understanding and provide certain points of reference that can become the subject of further discussion. In this context, the term "discussion" refers to a flexible and participatory model that actively incorporates stakeholder feedback and recent scientific findings to revise or replace consequences as necessary. In this context, consequence indicators serve as a reference point, whether in interactions between stakeholders and researchers or solely among stakeholders. Thus, we suggest that stakeholders should have a central role in designing the scenarios (and the matrix). The modeling process would start with the overarching research topic, which is raised by the researchers. For instance, in our case, this would be water conflicts. The next steps will be to conduct interviews with relevant stakeholders and collect supporting literature from the internet. Interview questions could focus on current conflicts, the parties involved, actions taken, or that could be taken, and potential impacts. Information on the relevant parties, their actions, and the potential impacts or consequences can then be used to create an initial CIB matrix. This matrix can then be used to facilitate follow-up sessions with stakeholders, in which the appropriateness of the results (scenarios) depicted by the matrix can be assessed. Depending on the feedback received, changes may be made to the parties involved, their actions, the consequences, or a combination of these, based on the stakeholders' assessment. Finally, once this feedback has been collected alongside the additional research data, an improved matrix can be created. This is an iterative process involving multiple stakeholders, and we recommend allowing stakeholders to share their experience and review the scenarios at each stage. As this is an iterative process, there is no fixed order for completing these steps, especially with regard to adding the influence values. However, it is advisable to follow this approach when creating the elements of the matrix: "Who acts" (descriptors), "What can/do they do" (variants), and finally "What consequences can these actions have" (consequence descriptors). The influence values are usually determined once the descriptors have been connected, using information from stakeholder discussions or literature. However, it should be noted that this sequence does not always apply in practice, and multiple feedback loops (iterations) are both possible and advisable. However, it is advisable to adhere to the overall structure and key elements to ensure that the focus remains consistent throughout the work. In addition, a possible step-by-step procedure is outlined at the end of this section as a guide for application.

Figure 1 illustrates a simple version of the CIB matrices concerning our consequences explication: In contrast, within a standard CIB matrix, the descriptors (D) are utilized to influence each other, thereby establishing the scenarios that can subsequently be analyzed, including the potential assessment of consequences. Our new approach tries to bring this assessment into the model, as the variants of the descriptors are modeled to interact with each other and influence certain variants, which function as central indicators of the system. This new extension of descriptors we call Consequence Indicators (C), and they are not intended to influence other descriptors directly, as they play the role of a passive system indicator. In conventional CIB modeling, fixed influence values are assigned to all variant interactions. In contrast, as our approach treats the consequence indicator descriptors as passive elements, meaning they have no influence values and do not exert effects on other descriptors. The methodology deliberately avoids establishing a numerical relationship between the consequences and the other descriptors, thereby giving participants autonomy. The objective is to utilize these consequences as a point of discussion to reflect one's viewpoints, as well as to enhance the overall matrix, if deemed necessary. As these consequences do not exert influence on the other descriptors, the relevant stakeholders are given more autonomy in terms of determining the assessment of such consequences. Thus, this flexibility allows stakeholders, whether involved in matrix development or scenario evaluation, to choose or adapt the descriptors according to their viewpoints. For example, looking at which descriptors (D) influence consequences (C), or how stakeholders view a consequence, influences them. This approach recognizes that a scenario viewed negatively by one stakeholder or party may be viewed positively by another and keeps such assessment open for workshops. The same can be said of the modeled consequences, which could be viewed positively, negatively, or even neutrally. From a modeling perspective, however, this classification is irrelevant because they are primarily system indicators. Furthermore, keeping influence values open helps to mitigate discrepancies during matrix construction and retains adaptability for future changes. This flexibility could also allow for working with unfinished CIB matrices, if some consequences have already been defined with stakeholders before or during this process, serving as a foundation for the model development. These indicators are modeled in this way so as not to influence other descriptors, to avoid any potential for systematic determination, which will be discussed in more detail in the following section. This approach was developed primarily because of its intended application as a participatory tool and the focus on stakeholders (stakeholder interaction). We recognize that the modeling of this proposed approach may vary in practice, such as ensuring that D influences only C without creating

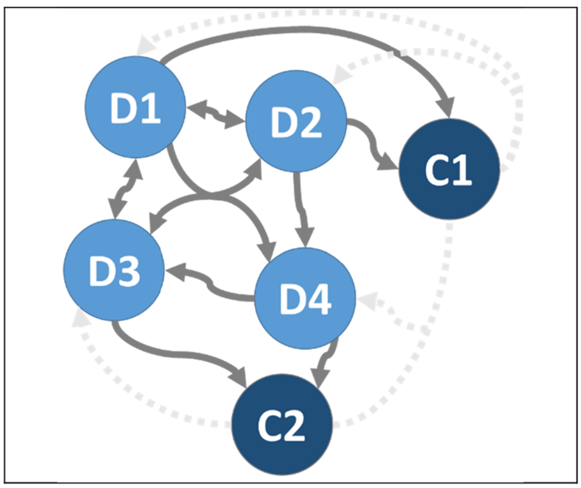

FIGURE 1 | Graphical representation of the consequence indicator approach - Descriptors (D1 to D4) influence one another, whereas consequence indicators (C1 and C2) are passive elements within the system that function as indicators to facilitate stakeholder adaptation of the descriptors. Therefore, it is possible to imagine an implied influence of the consequences on the descriptors.

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additional cross-impacts on other D. Furthermore, other CIB studies may employ similar passive indicators as C, although with different underlying reasoning. To focus on our new approach (an abstracted version) in action, we will show an example application in the following section while also explaining both descriptor types more.

3.3 | Methodical Considerations

Now, what are the implications for assessing the potential scenarios generated by both approaches? The CIB approach facilitates the generation of coherent variant constellations when all variant interactions are modeled numerically, effectively representing a structured set of scenarios. However, if the subsequent influence of a consequence is uncertain or deliberately left open, as in the proposed approach, where the consequence descriptors do not contain any influence values and are therefore omitted from the modeling process, the solution space expands. This extension also makes it easier during modeling if one considers consequences, but does not have to put them in the context of the other variants, because this may be difficult, or perhaps impossible. This freedom can be especially valuable when navigating complex scenarios in a workshop environment to test multiple potential scenarios. Consequently, the approach could be employed to concentrate on the behavioral responses of the participants. In what circumstances do they exhibit different behaviors, given that only the consequence and not its potential impact is illustrated here. This expansion occurs due to a reduction in restrictive interdependencies among variants, thereby allowing for greater flexibility in exploring potential system behaviors. While developing additional scenarios can be a valuable outcome of this approach, the primary focus of the consequence indicators is to foster engagement with stakeholders and their visions. The indicators are intended to provide a reference point for interactions and discussions between parties. Within this framework, empirical research could play a crucial role in examining stakeholder decision-making patterns. Through a systematic analysis of these behavioral dynamics, researchers could gain insights into the contextual factors that influence whether a consequence results in a discussion among the participating stakeholders. This process may involve refining model descriptors, adjusting variant representations, or identifying critical factors that influence stakeholder responses. In this regard, it is also possible to examine multiple rounds in which the individual engages with a series of scenarios until a solution is identified that appeals or no alternative appears preferable (e.g., the Nash equilibrium of game theory). Furthermore, such observations may contribute to a deeper understanding of the heterogeneity in stakeholder reactions, shedding light on how individuals or groups within the system may adapt differently based on varying contextual settings. Through this analytical approach, the modeling process can be iteratively refined to enhance its predictive and explanatory power within complex decision-making environments.

Finally, we want to outline how the proposed modeling approach can be implemented within a group setting. Drawing on best practice scripts group modeling (Wikibooks 2022), we propose the procedural steps for a workshop aimed at constructing a CIB model related to the given topic. Although this description outlines a single comprehensive session, the process can be segmented into multiple sessions or repeated as needed, depending on participant dynamics, the time required to integrate data into the software, or the need for a supplementary literature review.

A typical session could be structured as follows:

1. Concept Model Exercise: Participants are introduced to the CIB framework, including its functionalities and potential applications. In addition, the central focus on consequences and its incorporation into the CIB is presented.
2. Nominal Group Technique: This phase encourages participants to generate initial ideas relevant to the case or problem under consideration. During this phase, factors and their potential consequences should be explored.
3. Variable Elicitation: Building on the initial ideas, stakeholders engage in a guided process to refine and expand upon the variables of interest. This can be supported by the categorization of the ideas.
4. Ratio Exercise: Participants quantify the influence of one factor on another, which facilitates the construction of a tentative cross-impact matrix that maps out the directional relationships between variables.
5. Reflector Feedback: Iterative feedback sessions are conducted to refine the matrix, ensure its internal consistency, and reveal plausible future scenarios derived from the quantified interdependencies. For instance, an evaluation can be conducted to ascertain whether the consequences are sufficiently embedded or if improvements are required.
6. Key Take-Away Rounds: Intermittent summary sessions underscore critical insights and help enhance overall stakeholder participation.

4 | Application of the Approach and Initial Findings

To illustrate the method in an applied setting, we present the following example (see Figure 2). The following illustration of a matrix depicts potential water consumption in a hypothetical river basin. D1 to D3 depict the descriptors D, which are influencing each other, whereas C1 to C4 depict the consequences C that are incorporated into the model to provide context for stakeholders. Thus, this brief example already illustrates how conventional CIB models are extended through this approach.

In the figure, the descriptors or agents are industry, households, and agriculture. These agents have certain variants or actions, for instance, the industry has the option to expand production by increasing water use, investing in water efficiency, relocation, or maintaining current operations. Households have similar actions, ranging from increasing water utilization to low and high reductions, and the option to do nothing. Agriculture can shift its increased water consumption from river use to other forms of irrigation, invest in irrigation technology, change

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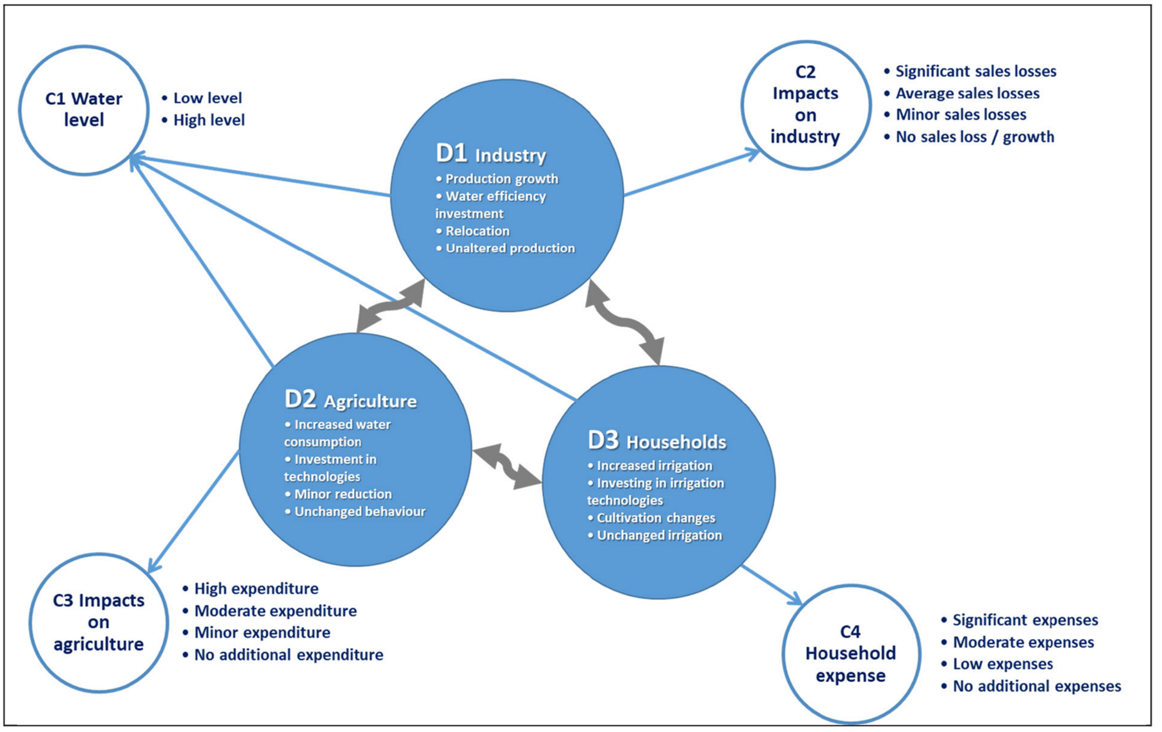

FIGURE 2 | Illustration of the descriptors of an exemplary CIB. D1 to D3 show the typical cross-impacting descriptors of a CIB matrix, while C1 to C4 are consequence descriptors that expand the model for the stakeholder involvement.

the cultivation method, or maintain its current behavior (rainwater). In the consequence approach, we use the same base and augment this model by incorporating direct consequences related to the agents. For this example, the included consequences are "impact on the industry" (e.g., potential sales losses), "household expenses," and "impact on agriculture" (e.g., potential expenses). In addition, we consider a system consequence relevant to all, in this case, for the river basin, a consequence called "current water level," which in this example varies between high and low.

In contrast to conventional descriptors, which provide only general orientations or general impacts for the scenario, C in particular can show vibrant effects that one may want to achieve or prevent. The method allows for clearly highlighting scenario outcomes, making it a valuable tool for further discussions. In addition to interactions, the consideration of consequences is also at the center, as we also heard in some interviews that people often plan for consequences. In the standard case, C is only a passive descriptor (water level), as we initially see this additional descriptor only as an orientation and system variable for the CIB. However, it would also be possible to give the consequence the possibility of influencing the other descriptors, both D and C, for instance, that the water level prevents the agent industry (D) from consuming water, or that several smaller consequences affect a larger one. However, this would defeat the purpose of the approach presented here, which is to embed in the model precisely this freedom and uncertainty, that interactions in the system may have consequences, but it is not clear how these may affect the system in the future. Nevertheless, this possibility shows that there are still possibilities to be explored, but these are not part of the basic modeling idea for the time being.

As suggested at the beginning, it would be suitable for use in workshops, both with one participant or several, as the first sessions show. In a one-to-one setting, it is possible to dedicate more time to exploring potential scenarios. A session would commence with the identification of the consistent scenarios of the matrix through the CIB software (ScenarioWizard). Subsequently, the respective variants selected by the participants can be used for filtering all the scenarios. The filtering process then shows one or more scenarios and their respective consequences, according to the specific case in question.

Finally, we would like to examine some preliminary findings from this section's discussed example. These results serve as an initial assessment of this proposed method and the possibilities this approach offers in comparison to conventional CIB models. However, they should not be regarded as a generalization, as further studies in different contexts are required. As illustrated in the example, the objective was to depict water conflicts that can be triggered by the actions of the water users. In this case, the participants are free to pursue their preferred course of action. Nevertheless, to comprehend the subsequent implications of their decisions, it is essential to evaluate the consequences of their options to one another and within the context of the system. This approach allows us to recognize the potential consequences of different courses of action and to determine which variants could lead to which consequences. We acknowledge that in this case, these mentioned results are relatively predictable, given that they are based on a limited number of factors and have been constructed in this demonstrative manner. For typical CIBs, which include numerous other agents and potential consequences and their interdependencies, this would be quite different. For instance, as one cannot grasp all the cross-impacts of larger matrices, the

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consequences of certain mixtures of variants may not be as anticipated. Nevertheless, even in this smaller illustrative matrix, we can still surmise the effect of using the consequence modeling, as they already can have a presenting character that is quickly graspable when viewing the scenarios. In terms of content, the matrix indicates that if the participants act in a self-interested manner and thus tap into the shared water, this behavior could lead to a consequence (low water level) for all. In the absence of this additional consequence, the direct relationship between the agents and the water impacts would be more ambiguous.

Initial external and internal reviews have provided valuable insights into the potential of this approach, reviewing all parts of the process. Regarding the internal reviews, these refer to the discussions about the model that took place within the project's research team. The external reviews refer to the exchanges with the relevant stakeholders. These evaluations underscore its suitability for workshop-based applications, emphasizing how its features can be leveraged to facilitate collaborative decision-making and problem-solving. Additionally, the reviews have identified various attributes of the approach that make the approach adaptable to different contexts, while also uncovering certain distinctions that may need to be addressed to optimize its effectiveness. As part of the external reviews, stakeholders from the Eifel-Rur catchment area in Germany, who had been involved at various stages in the development of the CIB, were consulted. Approximately 10 experts from industry, municipal administration, water supply and management, environmental organizations, and other water-related projects took part in the development. Their input was gathered during key stages, including framing the matrix, defining the consequences and agents in water conflicts, and subsequent review workshops of the matrix.

Throughout the process, the focus remained on tracing actions to their resulting consequences, ensuring coherence from the perspective of the interviewees. During the development of the model, interactions with stakeholders and a preliminary CIB matrix were undertaken, where having consequences as a reference proved beneficial. These stakeholders expressed a positive view on the flexibility and applicability of such an approach, noting how the approach aligns with diverse objectives and provides avenues for engagement. Meanwhile, internal team discussions have focused on refining the methodology, ensuring that the model meets both theoretical requirements and practical considerations. This internal team comprised several researchers with extensive experience in the CIB approach, enabling them to provide insights into the distinctions and potential applications of the new method. Within the scope of our study, we were only able to conduct this initial evaluation of our new approach. Consequently, we recommend further applications and additional research to enhance and validate its effectiveness.

Table 1 shows some of the initial hypotheses derived from the reviews, although there is likely to be more to be discovered or disproven when the approach is further assessed. However, this does not mean that these mentioned aspects always clearly apply to CIB, with or without consequences. Rather, this table suggests that studies could lean more towards one direction or the other when deciding on an approach. Our findings insinuate that modeling for consequences plays a more significant role in prompting a further examination of the model and consideration of potential options. Especially because you have the reference value (indicator) to build the scenario around. This discovery is also likely due to the enhanced ability to track the system's effects (consequences) and the impacts on them. Some stakeholders even mentioned this clear presentation of “simple” results as a fruitful first assessment on which to build further interpretations and discussions. In contrast, interactions in a typical CIB are often more abstract, which may limit their overall comprehensibility. Nevertheless, it became evident that it was precisely the consequences, that is, descriptor C, which became the focus of discussions. Without this, the topic remained at a superficial level.

Finally, we would like to illustrate the new addition of the CIB modeling briefly by using the XLRM framework, which is also a tool used for robust decision-making and supports decision-making under uncertainty (Groves et al. 2014; Lempert et al. 2003). Within this framework, the letters represent distinct components of a given model:

TABLE 1 | Initial comparison of CIB with and CIB without the consequence approach.

CIB model	Without consequences	With consequences
Reconsideration incentive	The abstract nature of the connections makes reconsiderations more challenging	Consequences give clear direction to rethink the behavior
Understandability from the perspective of a participant	Varies according to the understanding of the case; otherwise, interpretation may be difficult	System effects can be more easily reconstructed through the consequences
Center of the discussion	The scenario is rather the center of discussion	The consequences are the center of discussion
Scenario consistency analysis	Possible due to fixed cross-balancing	Consistency analysis is not equally possible due to the missing impact modeling of the consequences
Modeling effort	Easier because there are no additional reflection steps	More difficult, as the consequences have to be precisely harmonized

Abbreviation: CIB, cross-impact balance.

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- X (Exogenous Factors) signifies external factors or uncertainties that influence the decision-making environment, yet are beyond the control of decision-makers.
- L (Policy Levers) describes the near-term actions or strategies that decision-makers can implement to address the uncertainties.
- R (Relationships) are the connections or models that describe how the exogenous factors and policy levers interact to produce outcomes.
- Finally, M (Metrics) represents the criteria or measures used to evaluate the performance of different strategies under various scenarios.

The framework enables decision-makers to systematically explore a wide range of scenarios, identify vulnerabilities in strategies, and develop robust policies that perform well across diverse future conditions (Mannucci et al. 2023; Muñoz et al. 2024).

This fits the CIB concept and its consequence extension. First, we have the uncertainties or the problem (X) that we want to be assessed and gives the frame of the story and potential, and contributes to the overall model. Then there is the usual research around potential policies (L) that could help with these issues, which are developed with stakeholders and experts. The CIB matrix is the relationship (R) that can be used to identify scenarios that have the best working variants (M). In this context, the policy levers are also cross-checked against each other on how they would promote or impede certain developments. If we integrate our consequence modeling into this framework, then our addition is that we define some metrics, naming those consequences that can also help for iterative work on getting more input on uncertainties (X) and policies (L) for the stakeholders involved.

5 | Discussion

5.1 | Conceptual Foundations

As illustrated in this manuscript, the approach presents a novel avenue for CIB modeling (Weimer-Jehle 2006), particularly in terms of making potential consequences more tangible. The concept originated from the goal of fostering stakeholder engagement and interaction, recognizing that diverse perspectives can enrich a given case. Since cases often involve numerous actions as well as challenges, our focus was on enhancing the potential outcomes arising from the interplay of multiple factors within a scenario. In this context, "more tangible" refers to incorporating indicator descriptors into the matrix. Their purpose is to serve as reference points for evaluating interactions among other factors (descriptors). This addition aims to enhance stakeholder engagement by making CIB more accessible and providing clear reference points for stakeholders and researchers in their interactions. For the methodological and literary refinement of the conceptual basis, we used the CIB method (Weimer-Jehle 2024b), which offers a systematic way of incorporating qualitative and quantitative factors, as these must be integrated into this matrix and assessed in relation to each other. However, while this can provide a set of factors that promote each other (e.g., suitable scenarios), they could be considered too broad for assessment with stakeholders. Thus, in the context of offering more transparency in the model to improve engagement (Sciulli and Adhariani 2023) or decision-making (Bhatt 2024), as assessed in the literature, we adapted the structure of the matrix to focus on the system results (consequences). Thus, this approach involved creating consequence indicator descriptors to express such system results. Building on the concept of visioneering (Sand 2018), we see the opportunity to use this approach to funnel the visions of the involved stakeholders and assess their potential consequences for a certain case, with this being based on the mutual development of visions and futures. The idea here was to improve participatory modeling with CIB by linking it to the consequences of potential cases and building the model around this. However, it is important to note that this approach might simultaneously improve and increase the work of the modeling process, depending on the focus and topic of the study. The consequences that are incorporated into the system are additional descriptors that expand the whole matrix, and thus the interactions between the variants and the consequences that need to be modeled.

5.2 | Methodological Innovations

The primary methodological advancement here is the integration of a distinct descriptor within the CIB matrix. The proposed extension of the CIB framework integrates consequence indicators as passive elements (descriptors) within the matrix. These indicators do not actively influence other descriptors but are intended to inform stakeholder perspectives. Their primary function is to enhance the visual and intuitive understanding of system dynamics by making abstract numerical interdependencies more accessible. In this context, the approach also alters the dynamics of CIB modeling. The matrix is iterated around central consequences, which are intended to become the focal point of stakeholder discussions. In these discussions, the consequences are analyzed or modeled through measures that directly influence them. This is of particular importance during the preliminary stages of modeling, such as in workshops, where both cases and consequences are examined to determine appropriate measures. Furthermore, the use of these consequence descriptors allows for the easy incorporation of new consequences into the model, since when a new consequence is recognized, it is only necessary to update the relevant section of the matrix. Since they function solely as (passive) indicators within the model, they help simplify the overall modeling process. Still, the suitability of this approach depends on the focus of the model and associated study, which can have the aim of being more abstract or highly specialized. Because, as soon as more varied measures are taken, assessing all impacts becomes more challenging. Thus, we also recognize that while this approach has its use cases, the approach may not be useful for every study. For instance, when a research group has no stakeholder engagement or they are only interested in the interactions of the factors, then there might not be a need for this expansion. The possibility of incorporating such consequences at a later stage is, however, still possible and can be considered.

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5.3 | Practical Implications

With this approach focused on enhancing stakeholder exchange and considering the flexibility of the consequence indicators, one possible suggestion is to work with initial, uncompleted matrices. For instance, a preliminary matrix can be created, which provides relevant results but also allows for further adaptation. This option is particularly evident when considering participatory modeling, where such a model can provide a foundation but also sufficient space for different solution spaces (or feedback loops) to emerge from discourse about the matrix or the case in question. In this context, the consequence indicators are intended to facilitate interactions between stakeholders and researchers while also enhancing communication among stakeholders, as the consequences give a reference point to such forms of exchange. We recommend this approach for studies where it is crucial to identify potential system goals and determine whether they should be achieved or not. In particular, when considering multiple items simultaneously, it is beneficial to understand the degree of impact each might have. In this way, this method can be useful for discussion with stakeholders to present the interactions and results of the system in a concise form. Other practical implications are to use this approach for a quasi-discrete choice experiment. In these experiments, participants are presented with a set of factors, such as selecting a treatment based on the expected duration of illness, work capacity, sick leave, and cost (Manipis et al. 2023). As a result, the collective choices of all participants can define a set of preferences for a given case or scenario (Ryan et al. 2008). A comparable approach could be applied in this context using consequence indicator descriptors as the set of preferences. As can be seen in the example, participants are shown a certain set of consequences to which they can react in different ways. This could be used to see which variants are more likely to be chosen under which possible scenarios, or which variants are generally more chosen. This can be taken even further by including certain initial variables (a context), that is, a kind of initial scenario that was shown to the players in the first rounds of the game. In the case of water, this could be because it is a particularly hot year. This context could either just be mentioned or, as a kind of pre-determined descriptor/variant, influence the scenario itself. The consequence indicator descriptors (C) are designed for this case, as they are more stakeholder-oriented, in terms of both informing them and modeling the consequences through stakeholder feedback. Such stakeholder involvement can also be used to clarify a key question: How many consequences should my model have, and which are the "most important"? Given that the modeling of consequences is highly customizable and will depend on the focus of the research. In addition, both internal review and direct interaction with stakeholders can be used to explore and rank possible consequences for the matrix. As these consequences are modeled in a stakeholder-oriented manner, they can also be revised during the modeling process. In this case, they can be used as an infrastructure for an ongoing visioneering process (Sand and Schneider 2017). In other words, the stakeholders' visions are analyzed through the formalized CIB method, providing a structured framework that assists their expansion, reassessment, and broader exploration. This is due to the fact that CIB facilitates the initial unrestricted collection of ideas (visions), which must subsequently be integrated and systematically evaluated within the matrix framework, thereby undergoing a structured formal translation process. Therefore, there is no definitive answer other than that it depends on how many and which consequences are to be included, but at best, decisions should be made at an earlier stage, whether a study requires this focus on consequences or whether a study stays with a conventional CIB.

5.4 | Limitations

While the study provides encouraging early insights, its preliminary nature is evident from its reliance on initial findings. The current application of the CIB approach, particularly in accounting for stakeholder actions, remains in a developmental phase and requires further refinement. Future research should expand the data set, refine model parameters, and conduct comprehensive testing to improve the framework's accuracy and ability to capture the complex dynamics of stakeholder interactions. Conversely, this approach to consequence-based thinking can facilitate the development of structured modeling approaches, enabling the identification of key elements to be included and those to be excluded. While this strict focus on these elements (the consequences) can be assessed as a limitation, the approach also proves advantageous by demanding a thorough examination of each case to review potential consequences. However, it is possible that important consequences may be omitted or misjudged in such studies. Thus, it is helpful to involve a diverse group of stakeholders in the case and to consult with experts or relevant literature. Nevertheless, it should be noted that such scenario research will always have its limitations and will never be able to fully reflect reality. Fortunately, the passive nature of the consequences function allows for continuous adaptation in response to evolving circumstances. Due to the limitations of this scenario-based approach, we chose to place even greater emphasis on stakeholders. The goal is not to refine the realism of the matrix itself, but to explore possible futures with stakeholders in more detail, potentially enhancing perspectives for more informed decision-making. Since this new approach has only been tested within a limited case study and with a small number of stakeholders, the initial findings are promising but cannot be generalized yet. Stakeholders recognized the value of visualizing consequences within the model, but this must be reassessed in different contexts, including with other stakeholder groups or alternative consequence matrices beyond the focus on water conflicts. Additionally, as the approach was developed alongside stakeholder reviews, future studies could benefit from integrating this concept early on to explore the approach in greater depth. One limitation arises when the research objective is more narrowly defined, since consequence descriptors are not numerically modeled, they do not yield the same results as traditional CIB models. Therefore, if the aim is to generate specific scenarios, the approach must be framed accordingly. Overall, this method leans toward stakeholder engagement, providing a platform for them to assess their visions and the related consequences. While models adapted to the views of certain interest groups may naturally reflect biases, they can be appropriate in the context of the topic under investigation if enough diverse stakeholders are consulted. As a result,

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the findings are more influenced by stakeholders' perspectives and are less suited for generalization. However, the extent to which this holds true will depend on the diversity of stakeholder involvement in future studies and the intended application of the results.

6 | Conclusion

The objective of this study was to extend the CIB analysis for improving stakeholder involvement in participating in the modeling process. The expansion primarily entails the extension of the typical descriptors, in this study we call D, which can influence one another, by a more (for the participants) explicit descriptor variant, the consequence indicator descriptor named C. They serve as system indicators and can have positive and negative or neutral interpretations, depending on the given stakeholder. The initial assessment, in conjunction with stakeholder feedback, indicated but did not confirm that this approach might facilitate a more comprehensive understanding of the system and provide clear indications of the scenario itself by showing "simple" results, thereby enabling the determination of subsequent steps. Therefore, we suggest conducting further research on the consequence indicator approach in different stakeholder constellations to evaluate the possible validity of these indications. However, precisely because consequences are considered from the outset, they become part of the modeling and reflection process and thus the approach may facilitate a more comprehensive consideration of potential consequences. In this case, the consequences approach forms a structured base to assess visions and their consequences. The feedback loop that the consequences can trigger is a key consideration in both the modeling of the matrix itself and the external representation and possible behavior of participants. In our approach, the fact that the potential influences of the consequences on the other descriptors are not modeled is an opportunity for a stakeholder exchange, as this initially free-of-determination aspect of the model allows for a high level of flexibility in assessing multiple scenarios or possibilities.

In the context of CIB, the question arises as to how this advances the method or brings new possibilities to improve CIB iteratively. It is also worth considering which other parallel models are possible. Therefore, in addition to further evaluating the consequence indicator approach, alternative adaptations of the CIB method are conceivable and warrant investigation. This may involve investigating additional intermediate forms or analyzing other variables within the CIB matrix, such as potential modifications in the use of variants, to enhance stakeholder engagement. This reflection is particularly relevant when looking at which type of CIB could be best suited to which type of study. As the next steps, we propose a more comprehensive evaluation of the consequence indicator approach through follow-up studies, potentially exploring alternative frameworks to refine its application. Finally, the model also promotes the involvement of participants in the modeling process, including stakeholders, experts, and the public. As demonstrated by this study, the proposed approach could offer additional benefits not only to researchers but also to those who will be involved in the given project.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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