Deepening our understanding of which policy advice to expect from prioritizing SDG targets: introducing the Analytic Network Process in a multi-method setting

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Abstract

The indivisibility principle of the 2030 Agenda is considered key for the implementation of policies in pursuit of the Sustainable Development Goals (SDGs). Therefore, science is not only asked to develop new methods for assessing SDG target interactions but also to translate findings of methodological insights into policy advice for easy take-up by policymakers. The present paper demonstrates how to adopt the multi-criteria analysis technique Analytic Network Process (ANP) for prioritizing SDG targets in considering all positive and possible indirect SDG target interactions at once. The application of the ANP is linked to a multi-method setting embracing positive scores derived from the analytical methods Nilsson-scale, a cross-impact matrix, and network analysis techniques. This supports the prioritization of SDG targets when considering *n*-order neighbours in a network with respect to their synergies. The ANP allows evaluating the synergistic potential and progress controllability of SDG target rankings calculated by CI-matrix metrics and thus provides conclusions on the importance of *n*-order interactions of SDG targets in a network for the final ranking. We showed that the application of a combination of different analytical methods improves the overall quality of the formulated policy advice regarding its scope and methodological profundness. In this context, we compared the analytical methods involved with respect to their ability to formulate policy advice and finally presented a framing how to translate methodological results into concrete and applicable policy advice.

Keywords Sustainable Development Goals (SDGs) · SDG target ranking · Analytic Network Process (ANP) · Cross-impact matrix · Network analysis · Policy advice

Introduction

SDG implementation in the context of indivisibility

The 2030 Agenda was adopted by the UN General Assembly in 2015. Its fundamental aim is to transform the world to a sustainable development path while leaving no one behind (United Nations 2015), and this ethos is fundamentally linked to the Agenda's two key principles: universality and

indivisibility. Universality implies that the Agenda applies to all nations regardless of their levels of income. Indivisibility means that the formulated 17 Sustainable Development Goals (SDGs) should be implemented as an 'indivisible whole'. This interconnected nature of the SDGs is seen as axiomatic, even though the connections between the goals are uneven or that economic growth is prioritised over ecological integrity (Eisenmenger et al. 2020; McGowan et al. 2019).

On a political level, it is emphasized that it is currently unclear how to translate the indivisibly connected SDGs and their interactions into concrete efforts that support SDG goal achievement: most governments are not effectively able to simultaneously deal with multi-sectoral, multi-scale, and multi-actor issues created by the indivisible nature of the SDGs. In particular, it remains unclear how existing policies, instruments, and institutions will or even can adapt to meet

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the SDGs (Collste et al. 2017; Gusmão Caiado et al. 2018; Kanie et al. 2019).

Therefore scientists developed a huge variety of concepts, guidelines, and frameworks as what to governments must consider while implementing the SDGs: Sachs et al. (2019) proposed six major transformations to coordinate SDG interventions and concluded that policy coherence is needed across the various branches of government and between levels of government to guide these transformations. In this regards a proposed action agenda for science recommends the development of new tools that help to identify and quantify SDG target interactions as well as monitoring mechanisms to ensure sustainability transformation within the thresholds of the global planetary boundaries (Allen et al. 2021; Lu et al. 2015). Alternatively, Weitz et al. (2015) proposed the adoption of an integrated “biophysical nexus” using, for example, a water, energy and food nexus as the starting point for planning SDG implementation. Bowen et al. (2017) recommend three concerted efforts to address key governance challenges, with the first involving the fostering of collective action and the second to identify tensions between the simultaneous goal attainment of different SDGs and to address these trade-offs within SDG implementation. The third aspect of Bowen et al. (2017)’s plan is to ensure accountability for commitments made by various nations. Stafford-Smith et al. (2017) argue for realizing synergies in the SDG implementation, meaning to strive for action that supports the attainment of multiple goals at the same time. Furthermore, they highlight the necessity to integrate SDG implementation across industrial sectors, with societal actors, and in a manner that includes low-, medium- and high-income countries. In a similar vein, Lusseau and Mancini (2019) concluded that SDG targets should be contextualised because trade-offs differ according to country-income levels. The International Council for Science (2017) called for more coherence during the implementation of several SDGs, whether that be to overcome administrative silos or to more comprehensively consider SDGs interactions. Miola et al. (2019) developed two dashboards which combination allows to integrate “agreed” SDG interlinkages from literature with policy priority areas to develop policy implementation strategies. Reviewing the national implementation experience in 26 countries, Allen et al. (2018) concluded that key gaps appear because of missing interaction assessments between SDG targets (including both trade-offs and synergies). The implementation of the SDGs thus requires the identification of policy actions that maximise preferred policy outcomes through targeting the interactions inherent to the SDGs.

What drives the need for this type of multi-faceted research is the requirement to facilitate an integrated and coherent manner of SDG implementation derived from the UN’s focus on ‘the indivisible whole approach’ (United

Nations 2015). However, the ‘indivisible whole approach’ as a conceptual basis has not yet been comprehensively interpreted by the scientific community (Bennich et al. 2020). Against this background, scientists are being asked to translate the growing understanding of SDG interactions into usable policy advice and make this knowledge readily available for policymakers (Breuer et al. 2019; United Nations 2015). In their review article, Bennich et al. (2020) classified the literature concerning targeted policy challenges and analytical methods applied as well as a number of other categories. Based on this, they identify several policy challenges describing policy-relevant questions the scientific community has responded to so far. The perspective of highlighting the potential to formulate policy advice created by analytical methods and the latter’s ability to address specific policy challenges is still lacking.

Facilitating the analysis of SDG target interactions with the Analytic Network Process

SDG implementation is most often assessed by using one or a necessary sequence of analytical methods to evaluate SDG (target) interactions of single case studies. Bennich et al. (2020) report in their review that 37% of the considered publications report a multi-method approach indicating the application of more than one method. A closer look at these publications shows that specific bundles of methods were used in a combined way. A common multi-method application embraces a scoring based on the seven-point scale conceptualisation of Nilsson et al. (2016) (Nilsson-scale), the collection of this data in a cross-impact matrix (CI-matrix) allowing to derive SDG target rankings and also other network analyses based on the data arranged in the CI-matrix. However, applying single analytical methods only for a specific step of the necessary methods’ sequence excludes the possibility to learn from the pros and cons of different approaches. Only one article reports the application of different analytical methods being applied for prioritising SDG targets thus far (Allen et al. 2019). Evidence from this study points to the fact that the use of different approaches when assessing a given single case leads to different results and can potentially lead to different or even contradictory policy advice.

As previously said, how best to implement the SDGs raises the question of where to start. Accordingly, Breuer et al. (2019) proposed a roadmap for integrated SDG implementation where the first step is the definition of an issue-based entry point into the network of SDG interdependencies, in particular, to prioritise SDG implementation action (e.g. decide to focus interventions on SDG target 1.1). The issue of ranking SDGs or SDG targets is seen as critical because it involves inherent moral and ethical ramifications (Breuer et al. 2019; Pongiglione 2015). Only 20% of

recent studies have concerned themselves with prioritisation attempts (Bennich et al. 2020). However, in other sustainability contexts, the ranking of management alternatives using multi-criteria analysis approaches is a well-elaborated research area (e.g.: Cinelli et al. 2014; Kandakoglu et al. 2019; Mendoza and Martins 2006; Toth and Vacik 2018; Vacik et al. 2014).

SDG target prioritisation attempts have already been published considering trade-offs and synergies jointly. For example, Weitz et al. (2018) ranked SDG targets according to their net influence (the total influence of a single SDG target on all other SDG targets considering the second-order neighbours) and how SDG targets are, in turn, influenced by others. Additionally, the authors state: “The question arises how deep into the network and chain of influence the assessment should go; is it worthwhile to also account for third-order neighbours and beyond?” (Weitz et al. 2018, 542). Scott et al. (2017) surveyed 85 experts from several governmental and non-governmental institutions asking the question: which 20 of these 117 SDG targets should be tackled as part of a multi-year effort to fulfil all of the SDGs? A more recent study used an online consultation process for stakeholders that targeted 167 representatives, primarily from the private sector in Switzerland. As a result, the study identified 33 priority SDG targets by combining all the stakeholders’ responses and different statistical measures (Breu et al. 2020). Allen et al. (2019) used a multi-criteria approach, in particular, a weighted linear average to integrate results from 3 criteria (‘level of urgency’, ‘systemic impact’, and ‘policy gap’) to prioritise SDG targets. Additionally, they compared SDG target rankings derived from different analytical approaches (e.g., CI-matrix and network analysis measures) with respect to a single case study. There are arguments for handling positive and negative SDG target interactions separately as this might support a more in-depth analysis of the systemic role of the SDGs (Breu et al. 2020; Pham-Truffert et al. 2020). Furthermore, the application of analytical methods in a multi-method setting can provide benefits even if negative SDG target interactions are neglected (Allen et al. 2019).

The noted gaps in research can be addressed by applying the Analytic Network Process (ANP). The ANP is a multi-criteria analysis technique and the generalised form of the better-known Analytic Hierarchy Process (AHP). While the AHP is centred on the decision problem in a hierarchy, the ANP generalises the hierarchy into a network to better capture real-world interdependencies and processes. The ANP facilitates the decomposition of a decision problem into a network of its single elements to reduce the overall complexity. Further, the ANP provides the opportunity to consider the dependence of these elements and capture the feedback of the elements that often arise in practical decision-making. Feedback in this context involves cycles, which can lead

to an infinite process. The result of the ANP calculations is a prioritisation of the system’s elements with respect to the included clusters composed of system elements (usually criteria and alternatives) and the overall defined goal (Saaty and Vargas 2013). The ANP allows also to integrate different views and value pluralism for developing policy advice (Mulligan 2013; Munda 2019; Saaty and Vargas 2013) and is not limited to subjective qualitative evaluations such as scores; in particular, it allows to process various numerical data and empirical measurements as well (Adams and Saaty 1999; Saaty and Vargas 2013). The ANP has been applied in a diverse range of areas in the last few decades (Kheybari et al. 2020; Sipahi and Timor 2010) on topics entailing all three pillars of sustainable development. This includes business and financial management topics (economic pillar), issues of environment and energy management (environmental pillar) and questions of human resources management (social pillar) (Kheybari et al. 2020). Its application with respect to the SDGs which would thereby simultaneously integrate all the dimensions of sustainability has still not been undertaken. Therefore, we will demonstrate how to use the ANP for prioritising SDG targets according to their synergies and at the same time linking it to a multi-method setting embracing positive scores derived from the Nilsson-scale, the CI-matrix and network analysis. Furthermore, we will study if the consideration of third-order neighbours and beyond makes a difference in the evaluation of SDG target interactions to meet the indivisible whole requirement.

The paper is organised as follows: “**Material and methods**” presents the application of the ANP and all necessary steps in the data preparation and analysis. Section “**Results**” details the results of the application of the ANP to a case study in a multi-method setting and “**Discussion**” discusses the opportunities and limitations of the approach to draw some conclusions in “**Conclusions and further research**”.

Materials and methods

Methodological approach

To ensure that the description of the methodological approach of the multi-method setting is also readily perceivable for any reader—and perhaps not a specialist in the field of multi-criteria analysis techniques—we refer to a hypothetical SDG target network that serves as a simplified demonstration of the approach and follow the best practice checklist for ANP reporting (Mu et al. 2020). Hence, the reader is guided through the development of the (1) SDG target network model (see “**Model development, evaluation question and rating scales**”) and (2) the development of the unweighted and the weighted supermatrix (see “**Reporting the unweighted and weighted supermatrix**”). Upon this

basis, (3) the limit supermatrix containing the SDG target rankings is computed (see “[Computation of the limit supermatrix \(SDG target ranking\)](#)”). The application was performed using the free software product Super Decisions v.3.2.0 (SuperDecisions 2019a).

Model development, evaluation question and rating scales

The SDG targets serve as nodes in the ANP model and are contained in one inner-dependent cluster, meaning that all of the cluster’s nodes only depend on elements of this cluster. For the SDG targets (nodes) that show an interaction, links were established within the model to allow the integration of the respective SDG target interaction data. With respect to the hypothetical example, the SDG target network consists of six SDG targets (see ANP model in Fig. 1).

The common AHP/ANP application and its measurement procedure rely on data input that originates from a pairwise comparison of system elements using a pairwise-comparison matrix. In the hypothetical example, this would mean comparing the interaction of two SDG targets with respect to another single SDG target. As shown in the pairwise-comparison matrix concerning SDG target 1.1 in Fig. 1a, SDG target 15.1 demonstrates an interaction with SDG target 1.1 that is 1.5 times larger than the interaction of SDG target 1.3 with SDG target 1.1. Qualitatively and using the Saaty-scale, the interaction of SDG target 15.1 with SDG target 1.1 is ‘equally to moderately more’ larger than the interaction of SDG target 1.3 with SDG target 1.1 (Saaty and Vargas 2013). Conducting such a pairwise-comparison of all the system elements with respect to each other for each

SDG target would lead to six pairwise-comparison matrices, concerning the single SDG targets 1.1, 1.2, 1.3, 15.1, 15.2 and 15.3. This is shown with two exemplary matrices in Fig. 1a. Pairwise-comparisons allow consideration of the otherwise intangible (unmeasurable) relationship between two elements in the ANP. Based on the pairwise comparisons matrices, priority vectors can be calculated that include the relative ‘importance’ of the elements with respect to the single element they are compared to. These normalised priority vectors would then be collected in the unweighted supermatrix for further calculations (Saaty and Vargas 2013) (Fig. 1a).

However, the elicitation of the input data used for the application of the ANP to our case study follows a different procedure. The data is gathered using the Nilsson-scale asking the question ‘If progress is made on target x (rows), how does this influence progress on target y (columns)?’. As the underlying mathematics of the ANP relies only on positive values we only can use the positive interaction scores in our application. Two models were built, considering (1) the influence from a single SDG target on all other SDG targets and (2) from the perspective of a single SDG target, the influence received from all other SDG targets. For demonstration purposes, and with respect to the hypothetical SDG target network, only the model considering the influence from a single SDG target on all other SDG targets is presented (Fig. 1b).

All SDG interaction scores are then collected in a CI-matrix which shows the network under consideration and contains all the elements listed horizontally and vertically (Weitz et al. 2018). Hence, the CI-matrix is identical to the

Fig. 1. Hypothetical example: ANP model development and data input. **a** Data input for the ANP using pairwise comparison matrices **b** Data input for the ANP using Nilsson scores of the CI-matrix as direct data

initial supermatrix of the ANP (Saaty and Vargas 2013). The referring quantitative scores were subsequently put into the ANP model using the direct data entry mode in Super Decisions v.3.2.0 instead of the common pairwise comparisons and were therefore collected in the initial supermatrix (Fig. 1b) (Adams and Saaty 1999) to derive the unweighted supermatrix.

Consistency

The consistency check is an essential process step and usually applied instrument to prove if two corresponding scores (e.g. SDG target 1.3 directly influences SDG target 1.5 and SDG target 1.5 directly influences SDG target 1.3) in the initial supermatrix are logical in terms of the goodness or “harmony” of the two pairwise comparisons in the context of the total network (Bozóki and Rapcsák 2008). However, as we entered the data directly into the model and did not use pairwise comparisons, there was no need for the consistency check in our research. Nevertheless, the scores do not need to be consistent or even transitive to be further computed using the ANP (Saaty 1990).

Reporting the unweighted and weighted supermatrix

To elicit the priorities given in the scored SDG target interactions which were collected in the initial supermatrix, the local priorities (intermediate step to calculate the final priorities) for each SDG target are calculated by normalising their referring columns of the initial supermatrix, i.e., by calculating the relative influence of the SDG targets that summed up to 1 (see Fig. 1b). In other words, only the influence with respect to the direct SDG targets’ neighbours is considered in this step (1st order influence). For the columns including only one interaction (SDG target 1.3, SDG target 15.1 and SDG target 15.3), the normalisation procedure leads to the inclusion of these single SDG target with the relative influence of 1, regardless of their differences in the original score.

The unweighted supermatrix is accordingly composed of these normalised local priorities of all single SDG targets (Saaty and Vargas 2013; SuperDecisions 2019b). As there is

only one cluster used for modelling the SDG target network, no further calculations using weights for different clusters are needed as the unweighted and weighted supermatrices are identical (see supplementary material). For the hypothetical example, the weighted supermatrix is presented in Table 1.

To ensure that the weighted supermatrix is valid to calculate the limit supermatrix (final step to calculate SDG target rankings), we have tested the convergence of the weighted supermatrix with respect to the proposed heuristic of Mu et al. (2020) using R (R Development Core Team 2014). This means, that it is first checked to see if absorbing nodes exist in the network, indicating that a single node receives influence while not influencing other nodes. Additionally, confirmation is made that the columns of the weighted supermatrix are column-stochastic and therefore composed of normalised priority vectors. Absorbing nodes, as well as a non-column-stochastic weighted supermatrix, leads to a limit supermatrix primarily composed of zeros. Secondly, the weighted supermatrix is checked to see if sufficient links among the nodes are given to prevent the weighted supermatrix fragmenting into smaller subnetworks when calculating the limit supermatrix (Mu et al. 2020). The test result shows that the weighted supermatrix of the hypothetical example is suitable for the task at hand.

Computation of the limit supermatrix (SDG target ranking)

Theoretically, considering all indirect SDG target interactions for any case requires a self-multiplication sequence of weighted supermatrices W that tends to cycle to infinity: the weighted supermatrix itself, its square, its cube, etc., denoted by W^k where $k = 1, 2, \dots, \infty$. However, to consider all possible indirect SDG target interactions for a specific case involves a search for the limit of that particular sequence. Therefore, the primary goal is to obtain the limit supermatrix by raising the weighted supermatrix to powers by multiplying it times itself until the limit of $W^{n+1} = W^n$ is reached, indicating that the next powers do not add any detail to the result. For the weighted supermatrix, including a cyclic graph, to be relevant for the indivisibly connected SDG target networks, the average influence along all possible

Table 1 Hypothetical example: weighted supermatrix

	SDG targets					
	1.1	1.2	1.3	15.1	15.2	15.3
1.1	0.000000	0.200000	0.000000	0.000000	0.000000	0.000000
1.2	0.000000	0.000000	1.000000	0.000000	0.000000	1.000000
1.3	0.400000	0.400000	0.000000	0.000000	0.000000	0.000000
15.1	0.600000	0.000000	0.000000	0.000000	0.666667	0.000000
15.2	0.000000	0.400000	0.000000	1.000000	0.000000	0.000000
15.3	0.000000	0.000000	0.000000	0.000000	0.333333	0.000000

indirect SDG target interactions up to a given length is provided by the Cesaro sum $\lim_{k \rightarrow \infty} \frac{1}{N} \sum_{k=1}^N W^k$, where N is the limit of the sequence of the weighted supermatrices raised to powers (Rokou et al. 2012; Saaty 1999; Saaty and Vargas 2013; Sava et al. 2020; SuperDecisions 2019b).

When all the columns are identical, the limit supermatrix is converged into a stable matrix and the self-multiplication of the weighted supermatrix is halted. Hence, the limit supermatrix contains the SDG target ranking as the final priorities in each column (see supplementary material).

The rationale behind raising the weighted supermatrix to powers is to allow the SDG target network to be represented as a graph in the ANP and permit all direct and indirect SDG target interactions to be considered. Each transition within the network from one SDG target to the next is represented by the corresponding power of the weighted supermatrix. In other words, the power of the weighted supermatrix

corresponds to the orders of influence considered within the SDG target network. As the limit N of the sequence of the weighted supermatrices raised to powers is not returned by Super Decisions v.3.2.0, we call this the n -order influence. This is captured by the corresponding sequence of weighted supermatrices W^k where $k = N$. With respect to the hypothetical example, the process of raising the weighted supermatrix to powers is conceptually shown with the systemic understanding of the SDG target interactions in Fig. 2. The 1st order influence refers to the sequence of weighted supermatrices W^k where $k = 1$, the 2nd order influence refers to W^k where $k = 2$, the 3rd order influence refers to W^k where $k = 3$ and finally for the n -order influence W^k where $k = N$.

The columns of the limit supermatrix then establish the final priorities for the SDG targets. With respect to the hypothetical example, SDG target 15.2 is ranked best due to its highest influence on all other SDG targets in the network (Table 2), while considering the 1st order influence, SDG target 1.2 and 15.1 are ranked best (see largest row sum in the cross-impact matrix in Fig. 1b).

Sensitivity analysis

As we only used the ANP mathematics to calculate SDG target rankings, no decision alternatives and criteria are included in the ANP model and hence no sensitivity analysis can be performed regarding the effect on the prioritisation of alternatives.

Application to a case study

SDG target rankings in Weitz et al (2018)

The application of the ANP in a multi-method setting is demonstrated on the case study data presented in Weitz et al. (2018). The study analysed the interactions of 34 SDG targets to rank them according to their synergistic potential and with respect to their control over its own progress for Sweden. The study was chosen because of its available dataset, its comprehensive description of the analytical methods applied and its transparently constructed policy advice.

Fig. 2 Hypothetical example: a systemic understanding of SDG target interactions. Credit (SDG icons): United Nations

Table 2 Hypothetical example: limit supermatrix

	SDG targets					
	1.1	1.2	1.3	15.1	15.2	15.3
1.1	0.040650	0.040650	0.040650	0.040650	0.040650	0.040650
1.2	0.203252	0.203252	0.203252	0.203252	0.203252	0.203252
1.3	0.097561	0.097561	0.097561	0.097561	0.097561	0.097561
15.1	0.235772	0.235772	0.235772	0.235772	0.235772	0.235772
15.2	0.317073	0.317073	0.317073	0.317073	0.317073	0.317073
15.3	0.105691	0.105691	0.105691	0.105691	0.105691	0.105691

Re-calculation of SDG target rankings based on the CI-matrix

The application of the ANP to this case study data stringently followed all methodological steps examined with the hypothetical example as described in “[Methodological approach](#)”. The test result with respect to the proposed heuristic of Mu et al. (2020) shows that the weighted supermatrix of the country case study is suitable for the task at hand. For applying the ANP in a multi-method setting embracing positive scores derived from the Nilsson-scale, the CI-matrix, and network analysis, it is necessary to ensure that identical input data sets are used. Hence, as the ANP only allows processing positive interaction scores, the two SDG target rankings (synergistic potential and progress control based on the CI-matrix) are re-calculated after deleting those SDG target interactions that show a negative interaction score (see Fig. 3).

This procedure allows aligning the CI-matrix SDG target rankings with the ANP SDG target rankings. The re-calculation was done as follows: firstly, the total influence of the SDG targets on the second-order network was re-calculated as: $I_i^{\text{Total}} = D_i^{\text{Out}} + \frac{1}{2} \sum_{j \neq i} I_{ij} D_j^{\text{Out}}$, where D_i^{Out} is the out-degree of target i , I_{ij} is the interaction score of target i that influences target j and, finally, D_j^{Out} is the out-degree of target j . Of note here is the fact that the out-degree of a single SDG target is equal to its row-sum in the cross-impact matrix. Secondly, the SDG target ranking concerned with the total influence receiving from all other SDG targets with respect to the first-order network was re-calculated by taking the column-sum in the cross-impact matrix for each SDG target.

Fig. 3 Overall approach for re-calculation of SDG target rankings

Results

Application of the Analytic Network Process

As indicated in “[Model development, evaluation question and rating scales](#)”, two ANP models were employed to compute two SDG target rankings, the first ranking sorts the SDG targets with respect to their synergistic potential, i.e., due to their overall positive influence on all other SDG targets in the SDG target network. The second ranking orders the SDG targets regarding their control over their own progress, i.e., due to the positive influence received from all the other SDG targets in the SDG target network. The relative importance or priority of the SDG targets is shown in Table 3. The higher the priority, the better the rank. Regarding the progress controllability ranking it is important to note here, that a high overall level of influence received from all other SDG targets suggests that less control is inherent to the SDG target regarding its own progress, i.e., the worst ranked SDG target is the most preferred one in this context. The complete results of the re-calculations of the SDG target rankings of the Weitz et al. (2018) country case are part of the published supplementary materials.

Since the main research question was to understand whether it makes an empirical difference to account for 3rd order influence and beyond in SDG target networks in fulfilment of the indivisible whole idea, the authors team was encouraged to check if it makes a difference to consider more indirect SDG target interactions beyond the 2nd order influences when elaborating SDG target rankings. Therefore, the ANP was applied to analyse the n -order influence of the SDG target network. Table 4 compares the top 5 ranked SDG targets of the re-calculated CI-matrix/2nd order algorithm and the ANP for the two rankings for the case study data.

Overall, it can be seen that the ANP results are close to both SDG target rankings calculated by the CI-matrix approaches. The top-ranked SDG target is the same for each of the two rankings. For the rankings concerning the synergistic potential, the ANP ranks SDG target 8.5 4th, whereas it is not part of the top 5 derived from the CI-matrix/2nd order algorithm, where it is ranked 8th. Also of note is the fact that SDG target 9.5 is ranked 6th applying the ANP. With respect to the rankings concerned with the progress controllability, the ANP ranks SDG target 15.5 4th and SDG target 6.6 5th, whereas neither are included in the top 5 rankings calculated by the CI-matrix/2nd order algorithm. SDG target 15.5 is ranked 7th by the CI-matrix/2nd order algorithm and SDG target 4.4 is 12th. Conversely, the CI-matrix/2nd order algorithm place SDG target 13.2 and SDG target 12.1 in the top 5, whereas they are ranked 11th and 8th, respectively by the ANP.

Deepening our understanding which policy advice to expect

Analytical methods' potential to formulate policy advice

In considering the analytic dimension of the applied methods, we are evaluating their potential to formulate policy advice and to which policy challenges (Bennich et al. 2020) the policy advice can respond to. As shown in Table 5, the results of the various analytical methods provide a different perspective on the potential policy advices. The CI-matrix, the supermatrix of the ANP as well as network analysis methods produce results that respond to the policy challenge of 'policy prioritisation' as they are instruments guiding the identification of the most promising entry point into the network of SDG interdependencies. Furthermore, the network analysis methods allow the identification of political actors that are responsible for the achievement of specific SDG targets and hence the prioritisation of such institutions' stakeholder collaboration. Additionally, they create results that respond to the policy challenge 'integrated perspective' in the sense of promoting systemic thinking and learning of the involved decision-makers.

The ANP supermatrix and the CI-matrix allow calculating the same two SDG target rankings (synergistic potential, and progress controllability) (see Table 5). Weitz et al. (2018) argue that the calculation of the influence of single SDGs considering only direct SDG target interactions provides insufficient information to effectively guide priority-setting of SDG implementation action. Both CI-matrix approaches (CI-matrix and CI-matrix/2nd order algorithm) presented provide a ranking to the synergistic potential of the SDG targets differing only in their order of influence within the SDG target network that is considered (Table 5). The CI-matrix/2nd order algorithm method also processes indirect SDG target interactions by referring to the 2nd order influence and is, therefore, a more suitable SDG target ranking as the one provided by the classical CI-matrix because it includes a better information base. As with the two CI-matrix approaches, the ANP allows the ranking of SDG targets due to their synergistic potential. The ANP calculates the positive influence of the n -order SDG target network (see "Computation of the limit supermatrix (SDG target ranking)"), which allows the processing of more indirect SDG target interactions and leading to a more sensitive SDG target ranking, that might change when additional interactions are introduced to the network. Therefore, to guide policy-making on how to approach the SDGs without losing the indivisible whole idea, we argue that the ANP is more suitable to identify possible entry points of the SDG network than the two CI-matrix approaches. Additionally, both, the CI-matrix approach relying on the 1st order influence, as well as the ANP, provide guidance regarding whether progress

Table 3 ANP results: SDG target rankings

Rank	Synergistic potential		Progress controllability	
	SDG target	Priority	SDG target	Priority
1	16.6	0.067946	1.5	0.065546
2	8.4	0.060716	13.1	0.052345
3	12.1	0.060336	2.4	0.049379
4	8.5	0.045566	15.5	0.046410
5	12.5	0.043292	6.6	0.041714
6	9.5	0.042887	10.1	0.040204
7	4.4	0.042869	8.5	0.037492
8	5.5	0.041932	12.1	0.037234
9	9.4	0.040456	15.2	0.037073
10	7.3	0.037740	6.5	0.034224
11	13.1	0.036779	13.2	0.033470
12	13.2	0.035138	1.3	0.033240
13	1.5	0.034357	8.4	0.032216
14	1.3	0.034000	4.4	0.029821
15	11.2	0.032496	9.4	0.029552
16	16.4	0.031316	10.7	0.029033
17	2.4	0.029822	3.4	0.028803
18	5.4	0.028510	11.2	0.026900
19	7.2	0.028324	11.1	0.026388
20	6.5	0.026843	14.1	0.026053
21	4.1	0.025938	5.5	0.024441
22	10.7	0.017785	12.5	0.023927
23	11.1	0.017195	2.2	0.023540
24	2.2	0.016783	17.13	0.022874
25	17.13	0.016736	14.4	0.021721
26	15.5	0.015570	7.3	0.020780
27	14.4	0.015274	3.8	0.019732
28	14.1	0.014927	16.6	0.018545
29	10.1	0.014226	9.5	0.018408
30	15.2	0.010882	5.4	0.018029
31	3.8	0.009571	4.1	0.016756
32	17.11	0.009246	7.2	0.014747
33	6.6	0.008726	16.4	0.012182
34	3.4	0.005818	17.11	0.007223

on an SDG target is at risk of being neutralised or halted by progress on other SDG targets. The results of the SDG target rankings indicate the control possible over the SDG targets' progress. Translating this into policy advice means that actual SDG implementation should focus on those SDG targets that are largely autonomous, when it comes to their own progress as this significantly reduces the randomness of outcomes of any realised SDG implementation actions.

The network analysis methods presented allow to identify and to prioritize stakeholder collaboration as well as enhanced system understanding for policymakers. The identified sub-networks support the detection of influence paths within the SDG target network allowing to consider

Table 4 Comparison of top 5 ranked SDG targets of the re-calculated CI-matrix/2nd order algorithm and the ANP with respect to different SDG target rankings

Rank	SDG target ranking			
	Synergistic potential		Progress controllability	
	ANP supermatrix	CI-matrix / 2 nd order algorithm	ANP supermatrix	CI-matrix
1	16.6	16.6	1.5	1.5
2	8.4	12.1	13.1	2.4
3	12.1	8.4	2.4	13.1
4	8.5	12.5	15.5	13.2
5	12.5	9.5	6.6	12.1

Colour indicates whether the SDG target is ranked identically for both SDG interaction analysis approaches (green), the SDG target is included in the top 5 of both approaches (cyan) or not (red)

cost efficiency reflections of SDG implementation at a very basic level. Goal attainment of a specific SDG target may be approached by various influence paths embracing differing SDG targets that trigger this influence path. Therefore, several SDG implementation actions may be chosen to approach these different SDG targets which, in turn, reveal that the costs of a single SDG implementation action become a relevant factor for implementation planning. Approaching clusters of ‘positive mutual influence’ allows the identification of areas where success can be rapidly achieved regarding SDG goal attainment, while also revealing the negative links (trade-offs) between clusters that are crucial elements within the network. Additionally, the political actors playing a role within these clusters can be better identified as stakeholders and may build strategic partnerships (Weitz et al. 2018).

Improving the overall quality of the policy advice

The combination of different analytical methods comprises advantages and disadvantages in their ability to improve the quality of the provided policy advice, which raises the question of a suitable setting. Policy advice being generically formulated in terms of the “potential” insights and improvements from a methodological point of view is inadequate to guide policymaking for a specific situation. Translating the analytical methods’ results into concrete policy advice needs to consider one of the four basic types of advice that can be given to decision-makers: ‘Recommend For’, ‘Recommend Against’ and ‘Decision Support/Information’ (Dalal and Bonaccio 2010).

‘**Recommend For**’ is the typical conceptualisation of advice in the decision-making literature. In the context of SDG implementation, it could be the advice for choosing a specific SDG target as an entry point of the SDG target network or a recommendation for stakeholder collaboration. In the context of the case study application, a policy advice could be formulated: ‘Start SDG implementation

by approaching **SDG target 16.6** (*Effective institutions*)’, because it best supports the positive interactions in the SDG target network’. Relying on the SDG target rankings produced by the ANP provides a more solid information base, as it includes more indirect SDG target interactions, than the rankings provided by the CI-matrix methods. SDG target 16.6 is identified by the ANP as the target with the highest synergistic potential in the whole network (Table 4). Conversely, ‘**Recommend Against**’ could help to identify SDG targets that should be perhaps not prioritized in a specific SDG implementation due to their less control over their own progress (e.g., SDG target 1.5 in the progress controllability ranking, Table 3).

The advices ‘**Decision Support**’ and ‘**Information**’ supplement the decision-making process by providing information about the interactions of a specific SDG target within a network and by recommending different procedures regarding how to decide where to start SDG implementation. In the context of the case study application a policy advice could be formulated: ‘Compare the implementation costs of **SDG target 16.6** (*Effective institutions*) and **SDG target 16.4** (*illicit financial/arms flow*)’, because there might be different preferable compromises of implementation costs and direct/indirect approaching of SDG target 16.6. In particular, the influence paths in the sub-network of indivisible interactions indicate to compare the implementation costs for SDG target 16.4 and SDG target 16.6 as they have a bidirectional influence on each other and as it might be that the indirect support for SDG target 16.6 through an SDG implementation option targeting SDG target 16.4 is cheaper as the implementation option directly approaching SDG target 16.6. Furthermore, for these two SDG targets their inherent control over their own progress based on the ANP results could be taken into consideration when starting the SDG implementation. In the context of the case study example a policy advice could be formulated: ‘Consider the inherent control over their own progress of **SDG target 16.6**

Table 5 Potential of the analytical methods to formulate policy advice

Policy challenges	Results and policy advice	Analytical method
Policy prioritisation	SDG target ranking—synergistic potential Approximation of issue-based entry point into the network of SDG interdependencies	<p>CI-matrix The SDG targets can be ranked by their overall positive influence on all other SDG targets considering the 1st order influence in the SDG target network</p> <p>CI-matrix/2nd order algorithm The SDG targets are ranked by their overall positive influence on all other SDG targets considering 2nd order influence in the SDG target network (Weitz et al. 2018)</p> <p>ANP supermatrix The SDG targets can be ranked by their overall positive influence on all other SDG targets considering the <i>n</i>-order influence in the SDG target network</p> <p>CI-matrix The SDG targets can be ranked by the overall positive influence received from all other SDG targets considering the 1st order influence in the SDG target network</p> <p>ANP supermatrix The SDG targets can be ranked by the overall positive influence received from all other SDG targets considering the <i>n</i>-order influence in the SDG target network</p> <p>Network analysis The identification and prioritisation of stakeholder collaboration can be supported by visualizing the direct influence from and on other SDG targets from the perspective of a single SDG target</p> <p>Network analysis Using network analysis software for the identification of clusters of ‘positive mutual influence’, i.e., the SDG targets included show mostly synergies</p> <p>Network analysis The sub-networks (of indivisible and constraining/countering interactions) help to focus on those SDG target interactions that are important due to their multiple and strong influence on other SDG targets</p>
Policy prioritisation and integrated perspective	SDG target ranking—progress controllability Identification of SDG targets that show overall low control over their own progress	
Integrated perspective	Visualisation Identification and prioritisation of stakeholder collaboration	
	SDG target clusters of ‘positive mutual influence’ Identification of the cluster’s stakeholder and prioritisation of referring collaboration. Enhancing the system understanding	
	Sub-networks of indivisible and constraining/countering interactions Enhancing the system understanding by identifying effective SDG targets and influence paths	

(*Effective institutions*) and **SDG target 16.4** (*illicit financial/arms flow*)', because relatively less inherent control can introduce randomness of outcomes of realised SDG implementation actions. A high overall level of influence received from all other SDG targets suggests that less control is inherent to the SDG target regarding its own progress. Hence, it is easier to achieve these heavily influenced SDG targets by ensuring the achievement of those SDG targets that exert a positive interaction.

The SDG target ranking showing the progress controllability (Table 3) suggests that this dimension could be neglected in our application as both SDG targets are almost similar ranked with respect to their control over their own progress (SDG target 16.6 is ranked 28th and SDG target 16.4 33th).

Network analysis methods allow to visualize the importance of actors in a network from the perspective of a single SDG target. This can help to identify and prioritize stakeholders with whom collaboration can be beneficial. In the context of the case study example and if SDG target 16.6 is chosen to be approached directly, the framing as concrete policy advice could be as follows: 'Analyse if progress on **SDG target 16.6** (*Effective institutions*) may impede the progress of other SDG targets or if progress on other SDG targets may prevent progress on **SDG target 16.6** (*Effective institutions*)', because there might be resistance or the need to negotiate. In this context, the collaboration with those actors that are responsible for the achievement of specific SDG targets can help to improve the coordination process or can lead to a dilution of the desired implementation effects.

Referring to our case study application, these simplified examples demonstrate that the combination of different analytical methods improves the overall quality of the formulated policy advice regarding its scope and methodological profoundness. Additionally, the presented framing of methodological results as concrete advice may allow enhancing the to foster accepting and utilising it (Bonaccio and Dalal 2006; Dalal and Bonaccio 2010).

Discussion

Recent literature addresses policy challenges and gaps applicable to SDG implementation (Allen et al. 2018; Bennich et al. 2020). This has come about, at least in part, because scientists are now not only asked to develop new tools and methods for evaluating SDG target interactions but also to translate methodological results of SDG interaction analysis approaches into relevant policy advice to inform and guide SDG implementation in response to these policy challenges and gaps. This is a difficult task as the 'methodological profoundness' of such advice inherently depends on the methodological understanding of the approach used and of its

limitations. The ANP addresses many of the limitations of current approaches as listed by Ospina-Forero et al. (2020). It is easily scalable, i.e. enlargeable by additional factors, because it employs the software tool Super Decisions, an established and well-known product (SuperDecisions 2019a). The replicability of ANP application is given as the applied methods used for score elicitation as well as the subsequent steps to use this data to build an SDG target network are transparently and comprehensively described in the present study. The ANP model can be built for every region or country separately and thus allows a consideration of the socio-economic context in terms of their specific SDG target interactions. Additional contextual factors, such as good data availability are a prerequisite for the application of the ANP, which may not be given for countries in transition or developing countries. Additionally, the ANP allows a consideration of the directionality of the SDG target interactions, because its mathematics is based on graph theory. The validity of the ANP's mathematical foundation has been widely discussed in the literature and there is broad agreement about its' soundness in the scientific community (Toth and Vacik 2018; Whittaker 2007a, b). However, if more IT-based and highly mathematical models, such as the ANP, are applied to elaborate on policy advice, more expertise is needed to understand the black box 'software' and its related modelling assumptions. Hence, translating these methodological results into practice relevant advice is highly dependent on how methodological uncertainty is addressed which, if done well, may increase the likelihood that the advice will be taken up by policymakers (Brugnach et al. 2007; Gilbert et al. 2018).

The ANP allows to assess SDG target interactions by considering all possible indirect SDG target interactions. A limitation is related to the ANP mathematics, which relies on positive values only and needs to exclude negative values from SDG target interactions and hence neglects SDG target trade-offs. The re-calculation of the CI-matrix SDG target ranking concerned with the synergistic potential and relying on the 2nd order algorithm shows that the top nine ranked SDG targets of the second-order network presented in Weitz et al. (2018) are identical and in the same order as the respective rankings in the re-calculation. From a methodological perspective, this is evidence that neglecting a small share of negative interactions (8% negative interactions compared to the positive ones) may not change the overall SDG target ranking, at least that held true for the case presented here. Generally speaking, an SDG interaction analysis approach covering the best possible information base should allow processing the quantification of all positive and negative SDG target interactions. Furthermore, in doing so, it should also cover all the influence paths including all direct and indirect SDG target interactions within and among SDGs. Such an understanding may guide the directed development

of new tools and methods for evaluating SDG target interactions considering these methodological properties.

Current SDG implementation literature is primarily concerned with the conceptualisation of SDG (target) interactions (Bennich et al. 2020), although some authors have now begun addressing the understanding that SDG implementation action can be better optimised to support goal-attainment of different SDG (targets) simultaneously (Alcamo et al. 2020; Scharlemann et al. 2020). Hence, a methodological approach supporting SDG implementation should not only be able to evaluate SDG target interactions, but also be able to assess SDG implementation actions with respect to their direct influence on different SDG targets. This highlights that developing *ex-ante* policy evaluations should take place in the first step of making the complex computational task of calculating SDG target rankings. The ANP could support this easily based on its supermatrix, which allows to simply extend the model by including SDG implementation action beneath SDG targets.

Analytical methods can be evaluated in several ways. Ospina-Forero et al. (2020) developed broad, desirable qualities embracing scalability, replicability, specificity and directionality that should be adhered to by the second generation of SDG network estimation techniques and we recommend building upon them as additional comparison attributes. This is similar to what is discussed by Breuer et al. (2019), who reflected on several methodological limitations of the current approaches and highlighted the need for replicability, context-sensitivity (which matches with the specificity attribute of Ospina-Forero et al. (2020)) as well as the ability to rank SDG targets to formulate concrete policy advice for specific situations. Alcamo et al. (2020) presented the four characteristics of (1) Level of external data requirements, (2) Level of expert judgement, (3) Interactive and (4) Spatially explicit results to compare methods used for analysing SDG interactions in different case studies. Several differences can be identified among the approaches depending on the underlying evaluation aspects, however, a broad and systematic assessment of current methods and tools is still lacking. We focused on the potential to formulate policy advice as attributes to promote a better understanding of the analytical methods' properties and thus contribute to further close this gap.

All the presented SDG target rankings were initially based on data measured with Nilsson's seven-point scale (Nilsson et al. 2016), a mechanism which is not meant to measure the strength of SDG target interactions (Nilsson 2017). This indicates that the policy advice given are relative statements and not statements proffering absolute influence of SDG targets on one another. In particular, the results of any SDG interaction analysis approach relying on the Nilsson scale can only be interpreted with respect to the initial semantic meaning of the score, that is to say, the relative ability to make progress on a single SDG target depending on the progress of interacting

SDG targets of the SDG target network (Nilsson 2017). For example, the best-ranked SDG target with respect to the synergistic potential is the one that best supports the positive interactions within the SDG target network. From a goal attainment perspective, and considering the group of SDG network estimation methods relying on the Nilsson-scale, it leaves the question open of how to measure the absolute interaction dynamic of an entire SDG target network in the sense of a flow and stock conceptualisation for SDG indicator analysis. In particular, a positive interaction between two SDG targets is not conclusive evidence of how these two perform with respect to indicators and how progress on one SDG target improves this indicator's performance.

Additionally, the CI-matrix SDG target rankings are based on the calculation of a net-influence that do not reflect the distribution between weak and strong SDG targets nor the diversification of positive and negative SDG target interactions, all of which may 'dilute' the perception of potential trade-offs (Pham-Truffert et al. 2020; Weitz et al. 2018). Thus, a recent publication handles positive and negative SDG target interactions separately to develop a more distinguished classification of the systemic role of the SDGs (Pham-Truffert et al. 2020). A more distinct integration of the distribution of weak and strong SDG targets as well as of the diversification of positive and negative SDG target interactions into an evaluation may well improve the quality of the SDG target rankings concerned with progress controllability. The knowledge which distribution, respectively diversification is better than another may help to reduce the randomness of outcomes of realised SDG implementation actions. In this context, Pham-Truffert et al. (2020) highlighted that SDG targets may "buffer" systemic effects by having more weight from incoming rather than outgoing ties. Focusing SDG implementation action on SDG targets that have less inherent control over their own progress, as well as on "buffer" SDG targets, may hinder the unfolding of positive multiplication effects within an SDG target network.

The ANP validates both re-calculated SDG target rankings initially based on the CI-matrix in terms of approving the best-ranked SDG target, which indicates that these rankings are robust. The consideration of third-order neighbours and beyond makes a difference for the ranks 4–5 (see "[Application of the Analytic Network Process](#)") of the presented top 5 ranked SDG targets (Table 4), as they are not identically ranked for both the re-calculated SDG target rankings and the ANP. Allen et al. (2019) report a high degree of consistency across the rankings they compared, in the sense that seven of the top ten ranking targets were the same across the four different methods. However, the four methods lead to three different top ranked SDG targets. Another difference to our study, and what is acknowledged by the authors, is, that they neglected a minority (12% negative interactions compared to the positive ones) of negative

interactions applying network analysis methods. As there is no systematic comparison of 2nd order SDG target rankings with the *n*-order rankings as derived from the ANP, this result may not hold true in the context of other case studies. Important to note here, is the fact, that the priorities of the 3 top-ranked SDG targets considering the synergistic potential (16.6, 8.4 and 12.1) (Table 3) are very similar, indicating that small uncertainties regarding the interaction scoring could change the best-ranked SDG target. This procedure—applying several methodological approaches to a single country case study may contribute to overcoming the formulated impossibility of comprehensive validation tests for SDG target rankings (Ospina-Forero et al. 2020).

We identified influence paths within the SDG target network which provides the possibility to optimise the costs of SDG implementation actions. This is in a similar vein to Pham-Truffert et al. (2020) who presented positive self-reinforcing sub-networks that may serve as “cycle” orientated policy interventions. Nevertheless, the costs of SDG implementation actions may still be dependent on the particular SDG target that is being pursued.

With respect to the presented influence path of our case in the multi-method setting, costs may vary depending upon whether effective institutions (SDG target 16.6) are approached or whether an investment to prevent illicit financial and arms flow is planned (SDG target 16.4). This suggests then that the identification of cost-effective actions implementing SDGs inherently depends on the understanding of an SDG network and its related influence paths. Therefore, evaluations of SDG implementation actions cannot be separated from an improved system analysis of the SDG target interactions within the network. This is in line with the Independent Group of Scientists (2019) who emphasised that issue-based entry points should be used to address the underlying network of SDG interdependencies. Additionally, choosing SDG implementation actions that function as synergy driver supporting different goals simultaneously may also save financial resources in the long term (Alcamo et al. 2020). Also, policy actors have an important role in the implementation process, as they have different capacities and power to influence the uptake of SDGs on national, local or even multiple scales in different temporal dimensions. This can have an influence on policy development and the identification of cost-effective actions for implementing SDGs as well.

As the synergies and trade-offs of SDG target interactions are highly context-dependent (Lusseau and Mancini 2019; Warchoł et al. 2020), costs for a specific SDG implementation action, such as ‘establishing effective institutions’, may vary from country to country depending on circumstances. However, from a methodological perspective, there is still space for improvement regarding the restrictions of single influence paths concerning cost-efficiency. Orientating on assessable management entities, such as sub-networks and influence-paths, is both pragmatic and supports the identification of readily

undertakable steps for implementing SDGs but fundamentally conflicts with the aim to consider all indirect SDG target interactions. Indeed, restricting influence paths would necessitate that indirect SDG target interactions are deliberately neglected.

However, given the increasing amount of research on methods and the number of tools available for evaluating SDG target interactions, there is the need to locate the methodological perspective presented here in a broader context, such as in a structured framework or process enhancing the coherence of policymaking for the 2030 agenda (Breu et al. 2020; Nilsson and Weitz 2019).

Conclusions and further research

The present paper demonstrates how to use the ANP for prioritising SDG targets in a multi-method setting embracing positive scores derived from the Nilsson-scale, the CI-matrix, and network analysis. The additional application of the ANP allowed deepening the understanding of how the overall quality of the policy advice can be improved. By putting the methodological dimension of the analytical methods under the spotlight, we are able to classify their potential to formulate policy advice and to identify to which policy challenges the policy advice responds to. Additionally, we present how methodological results derived could be framed as concrete policy advice to support its applicability for the policy process with respect to a specific case.

As shown, the ANP allows consideration of all the positive and possible indirect SDG target interactions and, as such, can quantify “how target interactions ripple through the complete network, i.e., going beyond second-order interactions” (Weitz et al. 2018, 547). Obviously, a major future research question should focus on how to consider negative SDG target interactions as well in applying the ANP. The following items could be considered as starting point: (1) To handle positive and negative SDG target interactions separately and to develop an aggregated network analysis similar to recent publications (Breu et al. 2020; Pham-Truffert et al. 2020), (2) to design a mechanism and translate the positive and negative single interactions into positive preference values. This is similar to the fundamental thought to invert cost values into positive preferences as presented by Saaty (1996). Finally, (3) mathematical solutions to extend the ANP mathematics itself could be elaborated on. Another future research could develop an understanding which conditions of case studies allow to neglect a small share of negative SDG target interactions and support the application of the ANP and thus profit from the opportunity to compute all feed-back loops. Our methodological approach highlights a more general need, namely to develop a conceptional framework of the ‘SDG implementation system’ to allow systematic *ex-ante* evaluations of SDG implementation actions: first of all in this regard, such a framework

should embrace an understanding of the different estimation procedures of SDG (target) interactions (Ospina-Forero et al. 2020), their ability to quantify the number of orders of both positive and negative influence as well as direct and indirect SDG target interactions. Furthermore, the estimation procedures' point of intersection for measuring and governing goal attainment by using relevant (composite) indicators should be specified (Diaz-Sarachaga et al. 2018; Hák et al. 2016; Lyytimäki et al. 2020a, b). Secondly, the framework should include an understanding of how SDG implementation actions trigger single or numerous SDG targets and subsequently the whole SDG target network by activating their various indirect influences. Thirdly, it should also take into account an understanding of how to evaluate synergies and trade-offs, separately and in a synthesized form within and across boundaries linking national attempts to the global development agenda (Forestier and Kim 2020; Zhao et al. 2021). Finally, the newly envisioned framework needs to be shared with scientists, policymakers and the public (Bain et al. 2019) to support a societal discourse about realisable SDG implementation actions.

However, from a methodological point of view, systematic *ex-ante* evaluations of SDG implementation actions based on a shared 'conceptual SDG implementation framework' can only be elaborated upon by applying a combination of different methods and tools highlighting their advantages and disadvantages, in particular with respect to their potential to formulate policy advice. This indicates the need to elaborate an in-depth understanding of current methodological approaches to guide the choice toward the best multi-method application for approaching specific cases as well as their related policy challenges and gaps concerned with SDG implementation (Allen et al. 2018; Bennich et al. 2020; Vacik et al. 2014). However, to avoid 'paralysis by analysis', where the different methodological results remain unused, scientists will be required to develop new tools and methods that satisfy policymakers' needs (Allen et al. 2021; Lyytimäki et al. 2020a, b). The knowledge created and the experiences gathered while implementing SDGs using these approaches should then be made available to scientists, policymakers, and the public on a central web-based knowledge platform such as that presented by Nilsson et al. (2018). This allows the embedding of the current advances in methodological development and related application experience into a larger process of collaborative and transdisciplinary science-policy-public learning for implementing the 2030 agenda.

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