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# Adapting RRI public engagement indicators to the Spanish scientific and innovation context: a participatory methodology based on AHP and content analysis

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**Abstract**
The paradigm proposed by Responsible Research and Innovation in the European Commission policy discourse identifies Public Engagement as a key area for exchange and dialogue among multiple actors following an inclusive and participatory process. Two definite set of indicators have already arisen at European level to monitor Public Engagement activities in the Science and Innovation realm. Our study aims to propose a deliberative participatory process, which involves selected stakeholders, for the adaptation of the European indicators to the specific Spanish scientific and innovation context. The methodological procedure is of exploratory nature and will be based in a combination of, on the one hand, qualitative content analysis techniques for the in-depth study of the deliberative process and the generation of indicators; and, on the other hand, a multi-criteria decision analysis technique such as the Analytic Hierarchy Process for the prioritization of the indicators. The discussion will focus on the procedure to articulate stakeholders' values and use them as the basis for creating a context-based improved list of indicators. Two types of research questions arise: (i) Is the proposed methodology adequate for the adaptation of the European indicators to the Spanish context? (ii) What are the main indicators to monitor and to expand reflection on the public engagement in the Spanish science and innovation?

**Keywords** Participatory methodology · Deliberative methodology · AHP · Content analysis · RRI indicators · Public engagement

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## 1 Introduction

### 1.1 Responsible research and innovation and public engagement as a key area

Responsible research and innovation (RRI) is an interactive process by which societal actors become mutually responsive to each other. It aims at the acceptability, sustainability, and societal desirability of the research and innovation processes and its saleable products. RRI promotes a proper inclusion of advances on science and technology in our society (von Schomberg 2012).

RRI as proposed by the European Commission (EC) and the works under the auspices of the EC, involves six key areas: (i) Public Engagement, (ii) Gender Equality, (iii) Science Education, (iv) Open Access, (v) Ethics, and (vi) Governance. Thus, engagement of what they term "societal actors" or "stakeholders" is at the heart of RRI, being recognised as one of its pillars by the EC (Geoghegan-Quinn and European Commission, n.d.).

Articulating RRI systems requires the combination of different strategies and methods, the involvement of different actors (Stilgoe et al. 2013), and the consideration of context realities (Mejlgaard 2018). That is, RRI poses a great amount of complexity as regards research and innovation (R&I) practitioners or policy-makers. Hence, the need for the operationalisation of RRI practices is currently a hot issue.

As Cortiñas (2009) stated "society has been private of a fundamental right many years: the right of knowledge". Cuevas (2008) in the text Scientific Knowledge, Citizenship and Democracy, explained the relationship between science and citizenship that had existed until a few years ago. That is, the citizen in science has been an actor without a voice, who has received the results of scientific practice without giving his/her opinion about it.

This discourse is currently turning towards a democratic and participatory model, which seeks a relationship of equality between scientists and the public, and an informed public debate as the preconditions for forging socially sustainable public policies need to be translated into new processes of deliberative democracy (Durant 1999).

Two decades ago, Public Engagement (PE) functions were often performed as a sort of "goodwill exercise." (Neresini and Bucchi 2011). However, the concept of PE has been transformed within the last years and a variety of authors confirm that a general turning away from top–down models of communication towards increased focus on dialogue-based approaches characterises the development of this field (Bauer and Allum 2007; Krzywoszynska et al. 2018; Wickson and Carew 2014).

Empirical work shows that there is a great variation among countries and research institutions in the way they carry out the Public Engagement performance (Neresini and Bucchi 2011), hence the influence of context. The literature also remarks upon the risk of abuse of PE as an instrument to drive institutional interests or to inhibit debate (Macnaghten et al. 2014). To properly manage the inclusion of PE in science and technology (S&T) practice and policies, a consensual monitoring framework is still a pending subject. In this paper, an adequate deliberative framework is proposed on how to create such a PE monitoring system.

### 1.2 Approaches to monitoring the progress on public engagement

Some open debates tackle the matter of monitoring RRI in general and PE in particular. In April 2015, a group of scholars published the Leiden manifesto for Research Metrics which is based on the premise that "the problem is that evaluation is now led by the data rather than by judgement. Metrics have proliferated: usually well intentioned, not always well informed, often ill applied" (Diana Hicks and Wouters 2015). Other scholars reflect on whether PE challenges the current legitimacy crisis of S&T or it exacerbates that (Porter et al. 2012; van Est 2011). However, it is not the aim of our research to make balance or to critic the current discussions about PE, but to shed some light on the topic with a research of exploratory nature. That is, proposing a deliberative participatory methodology, which will allow discussing the already existing, agreed upon EU RRI indicators, and adapting them to our national context. That means that if during our deliberative process any of the previous mentioned appeared, we would always analyse that discourse with the aim of enriching the creation of the list of PE metrics (later indicators).

Since the early 90s, some efforts have been carried out to promote the participation of the general public in the development of scientific and technological initiatives (Chopyak and Levesque 2002; Joss 1999; Kasemir 2003). We want to highlight the recent study carried out by Arrizabalaga; Solans-Domenech; Radó-Trilla and Adam (2016) in which the authors thoroughly review the related literature in the search for PE indicators. The research methodology of the study is very systematic and complete regarding the engagement of societal actors in health research policies at international level. However, this study has been carried out exclusively at institutional level; that is to say, it includes indicators that allow an analysis of stakeholder engagement in research institutions such as universities, research centres, and health research institutes. Thus, this proposal, on the one hand, leaves out indicators focused on lower levels of aggregation such as projects or researchers and, on the other hand, those of higher level of aggregation such as policies.

Other proposals such as Neresini and Bucchi (Neresini and Bucchi 2011) also focus on indicators on the institutional level, but in this case, they analyse a total amount of 40 European research institutions of different areas of knowledge. They find that while most research institutions analysed have dedicated resources for PE activities, such activities are not yet considered essential. They therefore conclude that performance indicators and standards might prove of great support for institutions and policy actors only if they are committed to the purpose of public engagement and societal dialogue.

The EC framework programmes are promoters of the development of indicators for PE at a programme and project level (Meijer et al. 2016); both in a qualitative perspective (character of PE activities) and in a quantitative perspective (scope of projects carried out with distinctive PE features). On this account, the RRI Expert Group was created in 2014 under the umbrella of the EU scientific policy to propose indicators aimed at monitoring RRI (Strand et al. 2015). Other research initiatives, such as the *Monitoring the Evolution and Benefits of Responsible Research and Innovation* (MoRRI) project (Meijer et al. 2016), address the construction of comprehensive indicators to measure the implementation of RRI initiatives in European S&T policies.

These sets of indicators have been proposed for any research area and for all the aggregation levels: policy, organization, and project. They have been proposed at a general European level; however, discussions at national level have still to be fostered to include national specificities, i.e. the context.

The work we propose in this paper stems from the guidelines proposed in the document (Strand et al. 2015) where it is suggested the indicators proposed at European level be adapted to their respective countries. The recommendations stated at the end of the MORRI project also suggest that the indicators that appear in the final report are not country-specific and are more appropriate for benchmarking countries (Peter et al. 2018). Thus, they should be revised to monitor the concrete policy of a particular country, with all its specificities.

In the particular case of Spain, a few efforts have been made to foster the concept of PE in our national scientific policy. In the current Law on Science, Technology and Innovation (Jefatura del Estado 2011), the term "citizen participation" is not always formalised in the law itself, nor at subsequent strategies and plans based on it, as a true "participatory approach" (in the sense of providing a formal regulation that allows citizens to exercise an active role in scientific deliberation). Instead, official documents tend to show a more conventional approach of "participation", focused on the promotion of scientific culture, the social acceptability of science, and the shaping of a positive image of a Spanish Research, Development and Innovation system (Revuelta, 2013).

The approach proposed will be based on the following three premises:

- Contextualization: adaptation of indicators to the geographic context: (Mejlgaard 2018; Ràfols 2019; Strand et al. 2015)
- Participation and deliberation with a representative group of stakeholders (Haywood and Besley 2014; Ràfols 2019)
- Prioritization: to create a concise list indicators for the policy-makers (Dudo and Besley 2016; Strand et al. 2015).

Thus, in this paper, we address the following three main goals:

G1—To find out the relevant public engagement aspects from an RRI perspective.

G2—To create a list of indicators able to measure the selected relevant aspects.

G3—To prioritize the indicators to select the most relevant and therefore reduce the set.

To achieve G1, G2, and G3, a participatory and deliberative process with experienced stakeholders will be carried out. Therefore, the fourth goal of this paper will be:

G4—To demonstrate that a participatory process with experienced stakeholders is suitable for the tailoring of the European indicators to the Spanish RRI context.

The final aim being to demonstrate that our participatory procedure can be used for adapting the indicators to different contexts. To demonstrate the good performance of the proposed approach, we will use a specific case study with ten Spanish stakeholders. Once the good performance of the methodology has been demonstrated, several recommendations will be inferred to use it in a more general (and official) context and with a greater number of societal actors.

## 2 Materials and methods

To define a concise list or Public Engagement indicators for the Spanish scientific context, the following methodology is proposed (Fig. 1). It is based on the MCDA theoretical framework and consists of 5 steps. We indicate the type of research method used in each of them.

A preliminary description of the steps is presented in Sects. 2.1–2.5. The results obtained are presented in Sects. 3.1–3.5.

### 2.1 Analysis of the current list of indicators in European RRI

A search on the already published lists of EU indicators has to be carried out.

### 2.2 Selection of a group of Spanish stakeholders

Europe 2020, the European strategy for smart, sustainable and inclusive growth (Commission 2010), identifies civil society, as one of the links that together with the other actors such as the European Commission, other EU institutions, EU Member States, and regional and local administrations, must take part in the implementation of the strategy. These stakeholders should play an important role in the development of national programmes and in the monitoring of their implementation.

Therefore, one of the key issues of the methodology should be to correctly choose and include stakeholders identified in this strategy to be aligned with the EU Experts

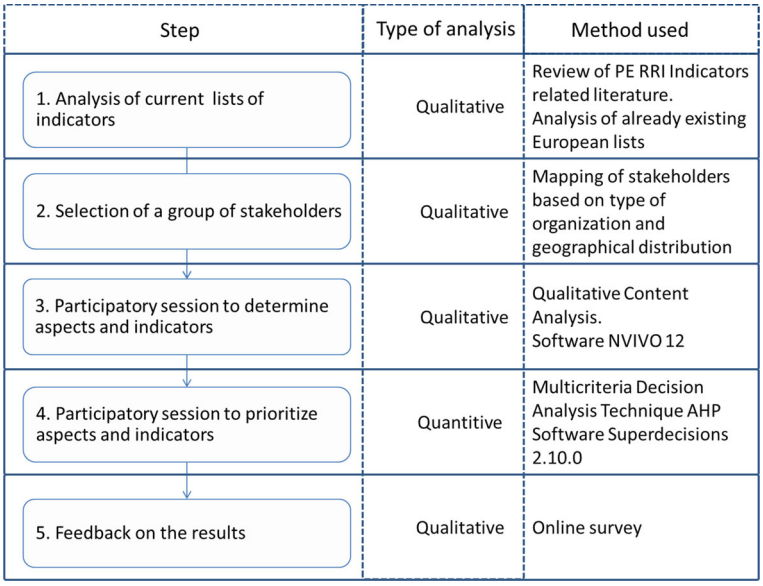


**Fig. 1** Methodological approach

Group PE strategy. If stakeholders get involved in the development of the indicators, they will become the "owners" of the monitoring, and therefore, they will more easily accept them as a valuable tool to improve their performance (Strand et al. 2015).

To endow the results with a higher value, it is advisable to have several experts take part in solving the problem of prioritization; these specialists are going to act as "decision-makers". For this study, we have included stakeholders considering the following premises: (i) they should belong to the categories mentioned in Strand et al. (Strand et al. 2015), (ii) an equal geographical distribution of the stakeholders in our country has to be attempted, (iii) they all have to be familiar with PE initiatives regarding scientific policies and should be among those affected by the ultimate monitoring procedure, (iv) there should not be any very high performing member in the group, since groups tend to give more weight to their input during group decision-making processes (Bonner et al. 2002), and (v) they are willing to participate, that is, have interest in the issue and availability enough in their agenda to spend 2 days in the participatory session.

### 2.3 Participatory session to determine aspects and indicators for PE (Goals 1 and 2)

This is the core part of the methodological procedure. We cannot forget that the aim is to demonstrate that our participatory procedure can be used for adapting the indicators to different contexts. As the good performance of the methodology will be demonstrated, recommendations will be inferred to use it in a more general (and official) context and with a greater number of societal actors.

To start with, information about the 2 initial lists of indicators at EU level was sent to the commissioned stakeholders before they came to participate in the sessions. The facilitators wanted to make sure that they were familiar with all the concepts and terms related to these PE indicators.

The methodology followed in this step was based on focus group and brainstorming techniques (Keeney 2012). In a deliberative process, decision analysts seek to integrate stakeholder values with technical judgments to find acceptable solutions (Belton and Stewart 2002; Gregory and Keeney 1994). Decisions made without enough social acceptance may be fragile, reducing the viability of the proposed alternatives (Grimble et al. 1997; Gutrich et al. 2005). This part of the study focused on a qualitative approach and a participatory initiative based on the opinions of these relevant actors (Ràfols 2019). The following research questions were addressed to the stakeholders at the beginning of the session and are one of the aims of our research methodology (details of the procedure are given in a later section):

RQ1. What are the PE-relevant aspects for Spanish science and innovation policies from an RRI perspective?

RQ2. Which indicators are appropriate to evaluate or monitor the selected relevant aspects?

### 2.3.1 Information collected from the participatory session

To tackle the first research question, we decided to explore the participants' discussion in the focus group using qualitative methods. The focus group's discourse was recorded and fully transcribed.

To analyse such an amount of information, we conducted the technique Qualitative Content Analysis for the reduction and interpretation of the data according to Gläser et al.'s (Gläser and Laudel 2013) method. This strategy of qualitative research was carried out with the support of NVIVO-12® and consists of three different phases:

1. Identification and data selection: search for relevant information in the group's discussions.
2. Creation of a system of categories: following our interpretation, we extracted different parts of a text as relevant, and linked parts of texts to different categories. Extracting content means separating the relevant information from the text, subsuming into categories, and storing it separately for further processing. Our first level of categories was: co-creation, competence building, and policy. The system of categories was changing during the processing of data. This was achieved by adding sub-categories that were a significant part of the discourse.
3. Searching for patterns in the data: pattern recognition is identifying characteristic combinations of data, which is most easily achieved when data are grouped in categories and sub-categories. We identified opinions and attitudes in the different categories with the purpose of detecting repetitions or patterns that differ clearly from each other.

During the qualitative analysis, facilitators sought feedback regarding the interpretation of data, examining categories and themes for agreement, coherence, and accuracy. Any disagreements were resolved following a re-examination of the data and peer debriefing.

### 2.4 Prioritization of aspects and indicators (Goal 3)

The objective of this phase is to identify the more relevant indicators from the list obtained in the participatory session to produce a tailored-reduced set of indicators. Built upon the hypothesis that there are PE indicators more important to consider in certain S&T policies or projects (Estévez et al. 2013), the aim is to avoid overburdening policy-makers by discarding those with lesser impact on their policies and programs. In this phase, we asked the stakeholders to prioritize the PE indicators according to the specificity of Spanish S&T policies. For that purpose the Multicriteria Decision technique Analytic Hierarchy Process was chosen (AHP henceforth) (Saaty 1980).

AHP is a measurement theory based on the fact that the complexity of a multiple criteria evaluation problem can be solved through the construction of hierarchic structures consisting of a goal and several levels of criteria. In each hierarchical level, paired comparisons are applied using judgements with numerical values taken form the AHP absolute fundamental scale of 1–9. These comparisons led to dominance matrices from which ratio scales are derived in the form of eigenvectors of weight vectors. These

matrices are reciprocal and positive ($A_{ij} = 1/a_{ji}$). The synthesis of AHP combines multidimensional scales of measurement into a single one-dimensional scale of priorities (Lidinska and Jablonsky 2018). In our case, these priorities will be calculated for the Public Engagement Indicators.

The AHP method is one of the most extended multi-criteria decision-making techniques. In particular, it has been applied in the RRI field (Ligardo-Herrera et al. 2018, 2019; Monsonís-Payá et al. 2017; Otero-Hermida and García-Melón 2018) and, also, in general PE issues related to policy-making (Bertsch et al. 2016; De Luca 2014; Higgs et al. 2008; Ignaccolo et al. 2017; Pira et al. 2015). It has the advantage of being easy to explain to the stakeholders assessing the indicators. This aspect becomes very relevant when the methodology has the aim of being further generalized to broader contexts.

More details on the AHP can be found in (García-Melón et al. 2016; Ishizaka and Labib 2011; Saaty 1994, 1980; Saaty and Peniwati 2008; Vargas 1990). Although AHP is a widely used MCDM method, it is not free of criticism (Maleki and Zahir 2013).

The prioritization phase required the completion of AHP-based questionnaires generated by the facilitators and answered by the stakeholders. The questionnaires were sent via email and processed with the help of Superdecisions © software.

### 2.5 Feedback on the results

After processing the responses using Superdecisions software, results were calculated both for individuals and for the group.

## 3 Results

In this section, we will present how the methodology was implemented and all the results obtained during its different stages.

### 3.1 Analysis of the current list of indicators in European RRI

As mentioned in Sect. 1.2, two lists of already existing PE indicators at EU policy level [Strand et al. (Strand et al. 2015) and Meijer et al. (Meijer et al. 2016)] were identified and used as basic references to develop the Spanish indicators.

The Expert Group report (Strand et al. 2015) published in June 2015 provides a list of PE indicators arranged according to three general aspects: (i) policies, (ii) event and initiative making, and (iii) competence building. Those indicators were also classified into perception, process, and outcomes.

The MoRRI report (Meijer et al. 2016) borrows ideas from the evaluation literature. It introduces the 'intervention logic model' as a starting point for monitoring various types of impacts and benefits of RRI. The intervention logic model is based on the explanatory idea that complex policy problems are characterised by a series of issues or problems that need to be addressed, a set of inputs which are applied to a series of

**Table 1** Participants

| EXPERT | Key actor group | Area of origin |
|---|---|---|
| 1 | State | Centre |
| 2 | Region | NE |
| 3 | University | SW |
| 4 | Research centre | Centre |
| 5 | Research centre | Centre |
| 6 | Research project | NE |
| 7 | City | NE |
| 8 | Research centre | SE |
| 9 | Civil society organization | NW |
| 10 | University | NW |
| 11 | Region | NE |
| 12 | City | NE |

activities, which generate outputs which in turn lead to outcomes or the resolution of the problems (Meijer et al. 2016).

Both the general aspects of the Expert Group list and the phases of the MORRI list have been used as a starting point for the Spanish context.

### 3.2 Selection of stakeholders

According to the guidelines determined in Sect. 2.2., 12 stakeholders were recruited to participate. In Table 1, their group and area of origin are shown. We made sure that in no case, any of the guests was subordinated to any other of them.

The number of stakeholders from the north of Spain is bigger, because it is where the richest regions are located and, therefore, the main research centres are based.

A total amount of 20 stakeholders were contacted, but only these 12 were finally recruited. They were invited to Valencia, where the focus group sessions took place. Later, they continued working on their own, at distance by means of internet communication tools.

### 3.3 Participatory session to determine aspects and indicators for PE

Two participatory sessions were held with the aim of establishing the panel of relevant aspects and indicators. These indicators were extracted from both the EU lists discussed in Sect. 3.1 and from the thoughts and experiences of the participants of the sessions themselves. The sessions were facilitated by some of the authors of this paper. An in-depth study of the deliberative process was carried out as follows.

During the first session, as an introduction, a brief explanation of the areas covered by the RRI and the different approaches was offered by the facilitators. The stakeholders were asked first to work in pairs and then in bigger groups to think about the

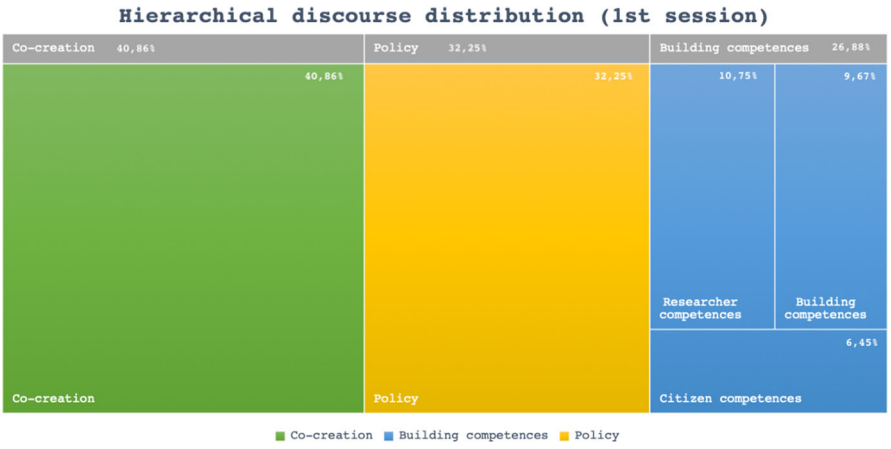


**Fig. 2** Tree mapping 1. First session. Discourse distribution

relevant aspects as regards monitoring PE and promoting the development of the RRI in the Spanish scientific and innovation framework. The three main topics according to the discourse analysis were co-creation, building competences and policy (see Fig. 2). These three categories were used as the dimensions to create and to structure the list of indicators in the second session.

With that, experts answered RQ1: What are the PE-relevant aspects for Spanish science and innovation policies from an RRI perspective?

The results of the first session were presented at the beginning of the second session. In this second session, participants were asked to discuss how to turn the set of aspects into a set of specific indicators; and also to classify them according to the three relevant aspects obtained. The discourse in this second session was deeper in the specific aspects of each category (Fig. 3). Experts acknowledged the two EU's lists of PE-RRI indicators, as previously introduced, but they did not have to follow them.

At the end of these sessions, all the indicators were organized in a hierarchical tree. A total amount of 20 indicators were listed for the three relevant aspects. In Table 2, the complete resulting list of indicators is presented with a detailed description of them, an analysis of the aggregation level, and the degree of similarity (identical, similar or new) with the previous proposed EU PE indicators.

We want to highlight a preliminary conclusion regarding this list. New indicators have appeared that were not in the European lists. This is due to the specificity of the Spanish national science policy. The EU indicators are too supranational to be applied in Spain. As commented, they may be more useful for comparisons among countries (Revuelta 2013).

In addition to the list of indicators generated, both sessions offer very interesting information to explore. A table with different quotas is provided at the end of this section to exemplify the information analysed (Table 3).

The following ideas arose through the interpretation of the focus group sessions (Gläser and Laudel 2013). In Spain, the policy dimension has the greatest weight to

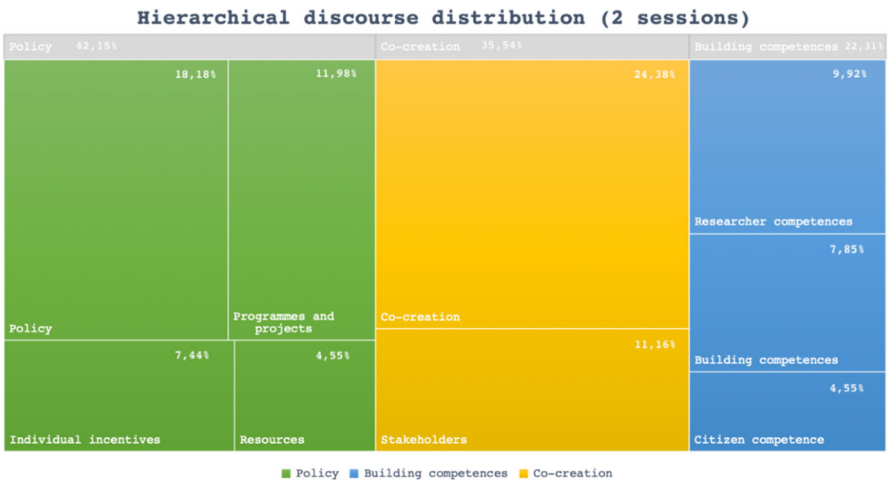


**Fig. 3** Tree mapping 2. Both sessions. Discourse distribution

change public engagement in science in accordance with the participants' discourse (see Fig. 3).

The discourse about the political dimension focused on the idea of the development of new kinds of research programs and projects based on: (1) explicit evaluation and valuation of the knowledge co-creation, (2) openness and transparency projects, (3) a bottom–up process by which different agents or civil society organizations, think up and lead research or innovation projects (contrary to projects lead by the scientific community), and (4) flexibility for the presentation format (breakdown with traditional extended monographs format). Additionally, in the policy category, participant interventions concentrated on the importance of economic resources allocation to encourage co-creation and the need of a specific investment in this topic at different institutional levels (national, regional, and local).

The second most debated topic was co-creation (see Fig. 3). The main participants' idea was about the need of a mentality change on both sides (citizens and scientific community). On the one hand, participants highlight the importance for citizens to give value to their scientific knowledge, and that citizens acknowledge science needs their contributions. On the other hand, researchers must trust collective knowledge and involve citizens during the whole lifespan of their projects, not just at the diagnosis level or for the data gathering. Participants argued strongly for the necessity of a new kind of participation and a real prominent citizen role. For this, a reconciliation and unity between researchers and society is needed. Also, participants stress the importance of incorporating new individual and collective actors with a special focus on minorities.

The last discursive category was building competences. Most of the discussion was about competences that researchers should acquire (see Fig. 3) rather than the citizens' competences. Participants did not reach a consensus on the type of training that researchers should have to encourage public engagement (formal and accredited education or informal). Citizens' competences were more consensual. They were about

**Table 2** List of indicators. Description and similarity with EU

| Code | Indicator | Degree of similarity with EU indicators |
|---|---|---|
| CB | Competence building | |
| CB01 | State of science journalism | Identical to the Expert Group indicator "State of science journalism" and similar to the sixth parameter "training and organizational characteristics of science journalism in a country" of the MORRI indicator "Science communication culture" |
| CB02 | Degree of exposure to scientific information (media, social networks, science museums) | Similar to the Expert Group indicators "Museums/Science Centres. Informal settings", "Media coverage" and "Social media/web 2.0 attention" |
| CB03 | Horizontal + vertical participation in science | Identical to the MORRI indicator "Horizontal + vertical participation in science" |
| CB04 | Public expectations of involvement | Identical to the Expert Group indicator "Public expectation of involvement" and similar to the MORRI indicator "Preferences for participation in decision making concerning science and technology" |
| CB05 | % of researchers with training in bidirectional communication | Similar to the Expert Group indicator "Training of scientists/engineers" |
| CB06 | Participation in networks (committees, associations, projects) | New indicator |
| CB07 | % of projects that develop initiatives with schools at institutes and research centres | Similar to the MORRI indicator "Specific activities with schools and research institutions" |
| CO | CO-CREATION | |
| CO1 | % of projects/initiatives of citizen science | Identical to the Expert Group indicator "Citizen Science Initiatives" |
| CO2 | % of projects/initiatives that identify stakeholders of the project/initiative | New indicator |
| CO3 | Diversity of actors in the projects/initiatives | New indicator |
| CO4 | % of projects of public engagement that are evaluated in regard to the public engagement | New indicator |
| CO5 | % of people that have participated in projects/initiatives of citizen science | New indicator |
| CO6 | Satisfaction of the expectations of the citizens after their participation in processes of public engagement | New indicator |
| PO | POLICIES | |
| PO1 | Total resources for public engagement (national level) | Similar to the MORRI indicator "Dedicated resources for PE at institutional level" |

**Table 2** (continued)

| Code | Indicator | Degree of similarity with EU indicators |
|---|---|---|
| PO2 | Formal commitment at national, regional or local level | Similar to the Expert Group indicator "Formal commitment" and similar to the MORRI indicator "Models of public involvement in science and technology decision making" |
| PO3 | Existence of incentives for researchers or mechanisms for official recognition of the participation in processes of public engagement | New indicator |
| PO4 | Existence of incentives for citizens or mechanisms for official recognition of the participation in processes of public engagement | New indicator |
| PO5 | Existence of specific calls for the development of projects by citizens or non-academic organizations | New indicator |
| PO6 | Participation of non-academics in public consultations of normative projects in the field of science, development and innovation | New indicator |
| PO7 | Participation of non-academics in councils and committees | Identical to the MORRI indicator "Community representatives in boards or committees |

empowerment and belief in citizens' abilities to engage in science. Also, participants remarked the need of a change in the common scientific culture to make it closer to lay people (see Table 3 for quotas).

With that, they answered RQ2: Which indicators are appropriate to evaluate or monitor the selected relevant aspects? Afterwards, AHP instruments were designed based on the findings and analysis of this qualitative research.

### 3.4 Prioritization: weighting of the aspects and indicators

To identify the more relevant indicators from the list obtained, next step was to prioritize them with the AHP technique. As explained, AHP assumes that the items to be prioritized can be arranged in a hierarchical model. By defining the relevant aspects and assigning the corresponding indicators, the hierarchy was thereby created.

An AHP-based questionnaire was delivered to each expert. They were required to pairwise compare indicators based on Saaty's fundamental scale of comparisons (1. Equal, 3. Moderate, 5. Strong, 7. Very strong, and 9. Extremely) to rank them. The responses were processed using Superdecisions® software. The individual and the group results were compiled.

Inconsistencies were checked, so that ratios were not higher than 0.1. (Saaty 1994). Two stakeholders (nr. 11 and 12) had inconsistency ratios higher than 30%, they were asked to reconsider their judgements but even after their second round, and

**Table 3** Discourse quotes. Example of the different categories according to the discourse

| Policy | |
|---|---|
| *Policy* | "A scientific policy that encourages a change towards a more participatory model (…) incorporate the public engagement as part of the institutional strategic plans" |
| *Individual incentives* | "Politicians have to generate incentives (…) incentives for the academic career and, also, institutional rewards. Incentives have to be based on economic resources" |
| *Programmes and policies* | "Calls must be improved a lot (…) if I do a call where I ask people to write a forty pages document and half in English, it is probably that the society do not feel part of this call. We need to rethink the calls (…) to be open enough to capture citizen's attention" |
| *Resources* | "At the same level that you obtain funding for materials or to conduct a survey, you should have resources to develop public engagement" |
| Co-creation | |
| *Co-creation* | "[it is needed] citizen empowerment in scientific issues. First, they need to have the knowledge and, then, be aware of their capability to share their necessities and everything that they consider as important" |
| *Stakeholders* | "(…) put in value the plurality of knowledge and recognise the value of those investigations that are carried out outside the academia or research centres" |
| *Building competences* | |
| *Building competences* | "There is a divorce between science and citizens. If you ask someone about the importance of science, he will tell you that it is important. But it is out of politeness because he really does not know why it is important" |
| *Citizen competences* | "(…) competences for the citizen to get involved more and in a better way, scientific culture, ability to participate in the scientific production…" |
| *Researcher competences* | "cultural change (…) about the kind of scientific results, scientific dissemination, what we are doing, how we are doing, how we are going to present our results or where…" |

the high level of inconsistency was maintained. Thus, for prioritizing matters, the judgements of those two experts were dismissed. Some others presented inconsistency ratios higher than 15%, but those were easily reduced by double-checking some of their answers with them. The inconsistencies were mainly found in comparisons within cluster policies. Some of them were also found in the cluster Competence Building, and surprisingly, none of them was found within cluster Co-creation.

## 3.5 Analysis of the results

### 3.5.1 Analysis of the group results

After having reviewed the inconsistencies and obtained the results, both the individual results of each participant and the preliminary group results were sent to each expert, so they could confirm them or, otherwise, modify any of their individual judgments.

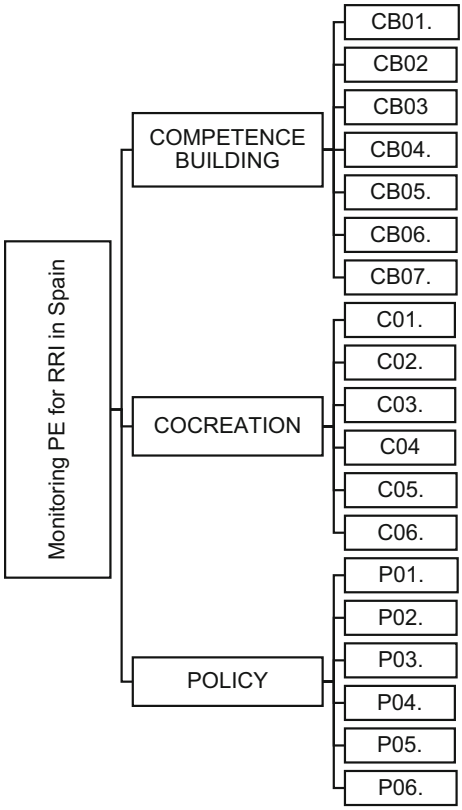


**Fig. 4** Hierarchical model of the indicators

After the consultation, the results of the method were deemed by the stakeholders to represent what they knew and to convey their experience on Public Engagement of S&T policies.

With the definitive responses, and as proposed by Krejčí and Stoklasa (2018), and Saaty and Peniwati (Saaty and Peniwati 2008), the aggregation of all the individual judgements was calculated by means of the geometric mean to obtain the prioritization by the group of stakeholders.

To present the results, we first show the aggregated results by main aspect. Then, we have arranged the stakeholders in three groups (Table 4): those belonging to: (i) universities and research centres, (ii) policy-makers of the public administration (state, region, and city), and (iii) researchers with expertise in PE (research projects of PE, civil society organizations) as stated in the introduction section. These results are presented in Fig. 5A and B.

These data show that in a given group of stakeholders, such as the one participating in this study, there are different perceptions about the importance of the indicators needed to monitor PE in Spanish the scientific context. Besides, as discussed later, also within a group of alike stakeholders, differences appear, although less remarkable.

**Table 4** Groups of stakeholders

| | Group | Number of experts |
|---|---|---|
| (i) | Universities, research centres | 3<br>Exp. 1, 6 and 7 |
| (ii) | Administration (policy-makers of the state, region, and city) | 3<br>Exp. 2, 3 and 8 |
| (iii) | Researchers with expertise in PE (research projects of PE, civil society organizations, and researchers with strong contact with sections of the public) | 4<br>Exp. 4, 5, 9 and 10 |

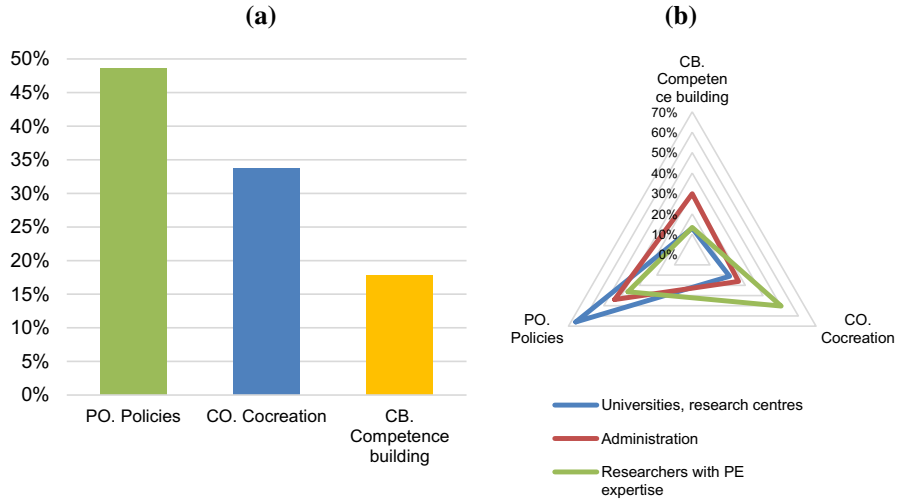


**Fig. 5** **a** Relevant aspects of public engagement in Spain. **b** Relevant aspects of PE in Spain by groups

According to these results, the most relevant aspect is *Policies* with a weight of 48,5%, followed by *Co-creation* with 33,6% and *Competence Building* with 17,8%. This is consistent with the importance given to them in the face-to-face sessions (Figs. 2 and 3). Hence, as even the group iii) of PE researchers and civil society organizations deemed *Competence Building* aspect less important, the actors' capability to participate is estimated sufficient, and the lack of public engagement is more due to the lack of support and certain barriers.

When analysing the groups' results in Fig. 5B, we can observe that the group (ii) of stakeholders who belong to the public administration for science is the one that has a more homogenous distribution of importance among the three aspects, the first one being *Policy* with a 44% of weight, as expected. The universities and research centres, group (i), also consider *Policy* to be more relevant, granting it a weight of 65%. This may be due to the financial dependence on the government-funded projects they carry out. On the other hand, the group (iii) of experienced PE researchers and

civil society organizations consider *Co-creation* as the most important aspect with 50% of the weight, which may be due to their first-hand knowledge and claim of the need to involve citizens and deal with them closely. Therefore, we can conclude that the results are consistent with the main concern of each group.

Second, we present the prioritization of individual indicators. The results for each indicator are presented in (Table 5, Fig. 6); both the individual prioritization and also the whole group prioritization are presented in the table. Also, in Table 5, the indicators with higher priority which amount to 50% of the weight are highlighted in bold.

This ranking allows us to identify the most relevant indicators to be taken into account when we want to monitor public engagement initiatives. In previous studies by the authors, this has been done by identifying the elements of the list that represent 50% or more of the total weight (Monsonís-Payá et al. 2017). The application of this cut-off rule will allow us to use a tailored-reduced panel of indicators for PE monitoring purposes, resulting in a more manageable list of items for a limited availability of monitoring resources (Fig. 7).

Therefore, the final list of proposed indicators to monitor PE in the Spanish science and innovation policy is

1. PO5: Existence of specific calls for the development of projects by citizens or non-academic organizations
2. CO6: Satisfaction of the expectations of the citizens after their participation in processes of public engagement
3. CO5: Percentage of people that have participated in projects/initiatives of citizen science
4. PO3: Existence of incentives for researchers or mechanisms for official recognition of the participation in processes of public engagement
5. PO6: Participation of non-academics in public consultations of normative projects in the field of science, development, and innovation
6. PO7: Participation of non-academics in councils and committees
7. PO1: Total resources for public engagement (national level).

The proposed indicators might have different levels of aggregation that is micro- and macro-level of application, e.g., policies, organizations, and projects. However, they all are applicable for the country-specific deployment of RRI recommendations and policies, that is to say, they overcome the problem of the indicators proposed so far, mainly devoted to the benchmark of the European countries' performance on RRI.

### 3.5.2 Analysis of the homogeneity of the judgements

Once we reached this point, we further analysed the performance of the participatory session to know how homogeneous the group was in its thinking. To find out which were the pairwise comparison judgments that meant the greatest consensus and which were the ones that presented the greatest differences. This aspect is relevant if we want to apply the methodology proposed to different context-based scenarios. To achieve this, we used the geometric statistical descriptors following the concept of *Monogeneity* defined by Saaty and Vargas (2007). *Monogeneity* relates to the dispersion of the judgments around their geometric mean, i.e., how homogeneous the judgments of the

**Table 5** Prioritization of indicators

| Indicator | Exp. 1 (%) | Exp. 2 (%) | Exp. 3 (%) | Exp. 4 (%) | Exp. 5 (%) | Exp. 6 (%) | Exp. 7 (%) | Exp. 8 (%) | Exp. 9 (%) | Exp. 10 (%) | Group priority (Geometric mean) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CB1 | 0.55 | 1.25 | 0.17 | 1.11 | 0.26 | 1.72 | 1.37 | 0.61 | 0.25 | 0.48 | 1.01 |
| CB2 | 0.63 | 2.68 | 0.33 | 1.58 | 0.38 | 2.04 | 2.19 | 1.07 | 0.47 | 0.69 | 1.58 |
| CB3 | 2.04 | 3.47 | 1.61 | 2.92 | 3.35 | 2.77 | 0.53 | 1.19 | 2.68 | 4.68 | 3.87 |
| CB4 | 0.47 | 1.20 | 1.01 | 0.15 | 3.17 | 1.11 | 0.53 | 1.07 | 0.91 | 2.85 | 1.60 |
| CB5 | 0.76 | 0.58 | 1.52 | 0.26 | 0.87 | 4.50 | 2.83 | 2.25 | 0.66 | 2.34 | 2.17 |
| CB6 | 0.55 | 3.36 | 0.47 | 0.26 | 0.65 | 6.64 | 1.37 | 0.31 | 1.31 | 3.23 | 1.87 |
| CB7 | 2.59 | 9.57 | 3.99 | 0.91 | 1.79 | 1.22 | 4.67 | 4.60 | 4.84 | 5.73 | 5.69 |
| CO1 | 4.94 | 1.86 | 1.78 | 14.79 | 8.26 | 3.06 | 2.64 | 18.44 | 7.00 | 3.07 | 5.63 |
| CO2 | 0.91 | 0.89 | 5.06 | 1.65 | 1.04 | 2.47 | 2.22 | 5.57 | 7.75 | 9.87 | 3.13 |
| CO3 | 0.95 | 6.21 | 3.74 | 6.24 | 1.04 | 0.85 | 4.04 | 7.43 | 3.31 | 14.55 | 4.01 |
| CO4 | 2.64 | 1.22 | 6.69 | 0.73 | 5.43 | 4.71 | 10.09 | 24.09 | 3.31 | 8.33 | 5.23 |
| CO5 | 3.18 | 10.30 | 10.98 | 1.19 | 3.10 | 2.94 | 6.87 | 18.82 | 36.72 | 4.65 | 7.56 |
| CO6 | 3.18 | 11.41 | 17.21 | 3.30 | 6.96 | 5.96 | 2.22 | 3.43 | 19.69 | 19.52 | 8.09 |
| PO1 | 25.14 | 3.38 | 2.77 | 20.91 | 8.66 | 11.77 | 14.97 | 0.42 | 0.22 | 1.05 | 5.96 |
| PO2 | 23.73 | 1.39 | 1.33 | 5.51 | 1.24 | 3.08 | 7.20 | 0.21 | 0.42 | 1.82 | 3.29 |
| PO3 | 11.26 | 2.48 | 8.66 | 10.59 | 6.94 | 1.81 | 16.53 | 3.97 | 0.49 | 2.14 | 7.38 |
| PO4 | 5.14 | 13.02 | 9.93 | 6.61 | 6.17 | 1.47 | 2.41 | 0.64 | 1.33 | 3.94 | 5.87 |
| PO5 | 3.33 | 11.96 | 14.87 | 17.72 | 12.12 | 20.80 | 5.54 | 3.10 | 1.99 | 5.74 | 12.34 |
| PO6 | 3.81 | 8.95 | 4.80 | 1.32 | 12.97 | 13.85 | 2.94 | 1.35 | 3.44 | 3.51 | 6.95 |
| PO7 | 4.21 | 4.82 | 3.09 | 2.26 | 15.61 | 7.21 | 8.83 | 1.41 | 3.22 | 1.79 | 6.77 |

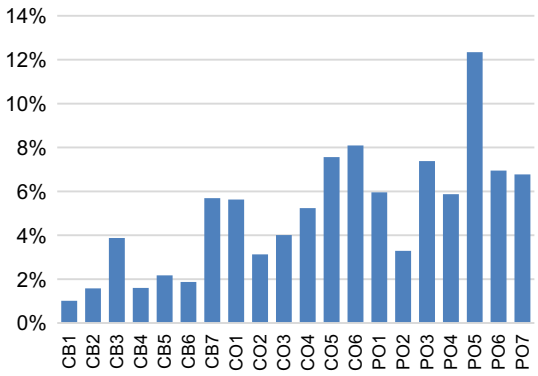


**Fig. 6** Group priority

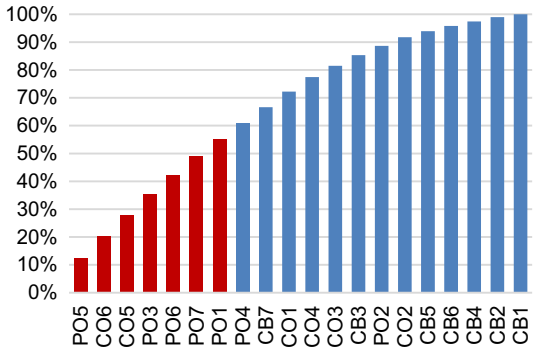


**Fig. 7** Application of the criterion "up to 50%" to select the most relevant PE indicators for the group of stakeholders

members of a group are for each judgment they give in response to paired comparisons. This is done by deriving a measure of the dispersion of the judgments based on the geometric mean

$$\mu_{Gj} = \pi_{i=1}^{n} Xij, \tag{1}$$

being Xij de judgement elicited by stakeholder *i* for pairwise comparison *j*.

This measure we need is the geometric standard deviation

$$\sigma_g = \exp\sqrt{\frac{\sum_{i=1}^{n}\left(\ln\frac{x_{ij}}{\mu_{Gj}}\right)^2}{n}}. \tag{2}$$

By analysing the result of the geometric standard deviation, we can determine which of the judgements offer the lowest homogeneity, those that have obtained the highest geometric standard deviation.

The results of this analysis are presented in Table 6. We present the geometric mean and standard deviation of each single pairwise comparison.

The following interesting results can be inferred from analysis of Table 6. In the case of the pairwise comparisons within the *Competence building* cluster, we can

**Table 6** Geometric standard deviation for judgements elicited for all the comparisons

| | Pairwise comparison | Geom mean | Geom standard deviation |
|---|---|---|---|
| Comparisons in CB cluster | CB1-CB2 | 0.465 | 2.637 |
| | CB1-CB3 | 0.263 | 2.485 |
| | CB1-CB4 | 0.607 | 4.684 |
| | CB1-CB5 | 0.440 | 3.608 |
| | CB1-CB6 | 0.517 | 3.575 |
| | CB1-CB7 | 0.267 | 3.632 |
| | CB2-CB3 | 0.448 | 3.623 |
| | CB2-CB4 | 0.851 | 4.426 |
| | CB2-CB5 | 0.530 | 3.629 |
| | CB2-CB6 | 0.750 | 4.304 |
| | CB2-CB7 | 0.316 | 3.370 |
| | CB3-CB4 | 2.807 | 2.196 |
| | CB3-CB5 | 1.764 | 3.538 |
| | CB3-CB6 | 2.273 | 3.608 |
| | CB3-CB7 | 0.649 | 3.563 |
| | CB4-CB5 | 0.719 | 3.256 |
| | CB4-CB6 | 0.719 | 3.685 |
| | CB4-CB7 | 0.344 | 3.262 |
| | CB5-CB6 | 1.052 | 3.076 |
| | CB5-CB7 | 0.286 | 2.118 |
| | CB6-CB7 | 0.241 | 2.521 |
| Comparisons in CO cluster | CO1-CO2 | 2.273 | 3.553 |
| | CO1-CO3 | 1.452 | 3.236 |
| | CO1-CO4 | 0.950 | 3.392 |
| | CO1-CO5 | 0.563 | 3.710 |
| | CO1-CO6 | 0.809 | 4.225 |
| | CO2-CO3 | 0.888 | 3.426 |
| | CO2-CO4 | 0.683 | 2.625 |
| | CO2-CO5 | 0.418 | 3.260 |
| | CO2-CO6 | 0.395 | 2.449 |
| | CO3-CO4 | 0.809 | 4.565 |
| | CO3-CO5 | 0.429 | 3.330 |
| | CO3-CO6 | 0.689 | 3.236 |
| | CO4-CO5 | 0.974 | 3.608 |
| | CO4-CO6 | 0.479 | 2.989 |
| | CO5-CO6 | 0.783 | 3.156 |

**Table 6** (continued)

| | Pairwise comparison | Geom mean | Geom standard deviation |
|---|---|---|---|
| Comparisons in PO cluster | PO1-PO2 | 2.350 | 4.091 |
| | PO1-PO3 | 0.701 | 3.655 |
| | PO1-PO4 | 1.018 | 4.937 |
| | PO1-PO5 | 0.549 | 3.828 |
| | PO1-PO6 | 0.782 | 4.741 |
| | PO1-PO7 | 0.754 | 3.739 |
| | PO2-PO3 | 0.357 | 2.560 |
| | PO2-PO4 | 0.517 | 4.405 |
| | PO2-PO5 | 0.365 | 4.023 |
| | PO2-PO6 | 0.567 | 5.240 |
| | PO2-PO7 | 0.487 | 4.244 |
| | PO3-PO4 | 1.205 | 3.423 |
| | PO3-PO5 | 0.517 | 3.149 |
| | PO3-PO6 | 1.016 | 4.670 |
| | PO3-PO7 | 0.983 | 4.075 |
| | PO4-PO5 | 0.530 | 2.782 |
| | PO4-PO6 | 0.823 | 3.390 |
| | PO4-PO7 | 0.743 | 3.688 |
| | PO5-PO6 | 2.141 | 3.144 |
| | PO5-PO7 | 2.197 | 2.715 |
| | PO6-PO7 | 1.274 | 2.589 |
| Comparisons between clusters | CB-CO | 0.467 | 3.140 |
| | CB-PO | 0.415 | 3.055 |
| | CO-PO | 0.612 | 3.448 |

identify the three judgements that have the lowest homogeneity among the different stakeholders, i.e., comparisons: CB1 vs. CB4, CB2 vs. CB4, and CB2 vs. CB6.

When moving to the *Co-creation* cluster, we do not notice any very low homogeneity. However, in the case of the *Policies* cluster, we can highlight that many of the group judgements offer a very low homogeneity among them. This could be due to the different level of aggregation of some indicators which makes it difficult to compare them, but also to the discrepancies among stakeholder on the role of policies, consistent with the long discussion in the face-to-face sessions. Thus, a reflection should be carried out on whether it is appropriate or not to have comparisons between indicators of different levels of aggregation. This aspect becomes very relevant, since the methodology has the aim of being further generalized to broader contexts. Moreover, in the first level of pairwise comparisons among clusters, we did not obtain any low homogeneity.

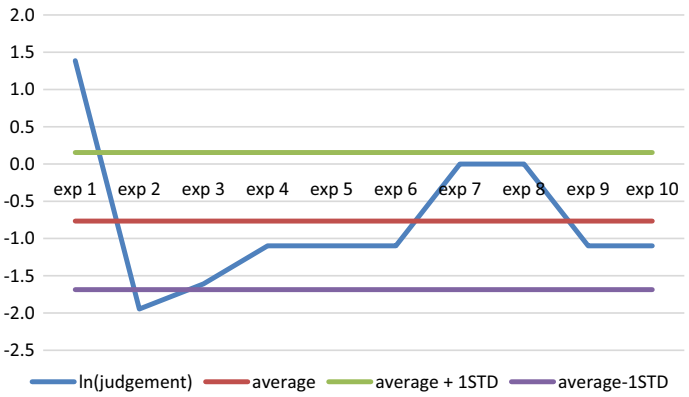


**Fig. 8** Statistical graphical representation pairwise comparison CB01–CB02

It is important to remark we have found a coincidence between the inconsistency of the pairwise comparisons and the geometric deviation of their judgements. Both inconsistencies and deviations from the geometric mean were mainly found in the CB and PO clusters. This opens interesting avenues for further research on the AHP method applied to deliberative participation.

Finally, to analyse these results with more detail, one can also focus in one particular pairwise comparison and analyse the dispersion of all the judgements elicited for it. Since the judgements have a lognormal distribution, we have calculated the natural logarithm of their geometric mean and geometric standard deviation to be able to represent these results in al linear scale. That way, the statistical graphical representation is easier to understand. For example, if we concentrate on the pairwise comparison CB01–CB02, the results of the judgements of all the stakeholders show (Fig. 8):

In this case, expert 1 was the one who showed the highest deviation from the mean. Both experts 1 and 2 issued judgements outside the 95% confidence interval.

We propose that this type of post-results analysis be carried out for all the pairwise judgments to assess the general evolution of the participatory session. This complete set of results could not be presented here due to space constraints. Nevertheless, for the analysis of the homogeneity of the group, these geometric statistical descriptors can only be measured once the judgements are elicited, and therefore, experts cannot be asked to repeat them again. However, they give us a good understanding of what and who might go wrong.

## 4 Discussion

The results presented in the previous section targeted the four main goals of this paper:

G1—To find out the relevant public engagement aspects from an RRI perspective.

G2—To create a list of indicators able to measure the selected relevant aspects.

G3—To prioritize the indicators in order to select the most relevant and therefore reduce the set.

G4—To demonstrate that a participatory process with experienced stakeholders is suitable for the tailoring of the European indicators to the Spanish RRI context.

The outcomes presented in Sect. 3.5 achieve the first three Goals. But then, our final aim is also fulfilled as the proposal of a deliberative participatory procedure which involves representatives of the relevant stakeholders, and its combination with AHP proves to be effective and satisfactory, which is stated in Goal 4.

Thus, our ongoing research can be mentioned as evidence of the viability of actually engaging stakeholders in, for example, the selection and prioritization of RRI indicators. Participation beyond a mere dialogue, and clearly beyond just informing stakeholders about the science practice and its outcomes. Stakeholders are expected to participate during the lifespan of this research.

The aspects and indicators thereby obtained are mainly quantitative, i.e., they are more devoted to determining the existence or not of PE, and its intensity, rather than devoted to assessing its characteristics. While taking advantage of the work of previous researchers (Meijer et al. 2016; Strand et al. 2015), context determines the proper approach towards PE. In Spain, quantitative indicators are considered still a necessary first phase of the monitoring of the PE in S&T, but not enough as discussed by (Diana Hicks and Wouters 2015). As PE starts off in the Spanish S&T realm, the quality of it will become the concern of an expected subsequent phase of the monitoring evolution.

The hereby presented methodology allows to go beyond the Top–Down vs Bottom–Up debate for PE metrics. The right selection of stakeholders enables a true constructive debate among representatives of all actors, in line with (Macnaghten et al. 2014; Strand et al. 2015). As a consequence, non-academic society has had a voice in PE promotion and monitoring, and this can be easily confirmed in the sort of aspects and indicators obtained. We believe that the implementation of a PE plan aligned with those aspects would clearly contribute to the social desirability and acceptability of research and innovation practices.

Moreover, the methodology is completed with an AHP-based Delphi-like procedure to continue the debate on the aspects and indicators. By asking the stakeholders to compare the PE indicators (aspects), questions as feasibility, immediacy, effectiveness, or reliability of the aspects are further discussed. This way, a prioritization of aspects can be determined, and a more efficient set of indicators can be arranged. Besides, the expectable lack of consensus can be dealt with by aggregating the individual judgements. This aggregation needs not waste the interest of the diversity. AHP allows a very detailed analyses of all individual preferences, agreements, and disagreements, contributing to a total transparency of the process.

Discussing the results, in the face-to-face participatory session, besides identifying the aspects and related indicators, the length of the session was recorded as well as the intensity and diversity of the comments on each aspect. This way, the main aspects could be advanced. Indeed, in the subsequent prioritizing phase, the most influential indicators (aspects) coincided with those topics previously more present and discussed (see Figs. 3 and 5). The five more influential indicators are all new, i.e., not advanced in the EU's lists, proving the need to reflect on the specificities of each context, beyond merely adapting the already existing proposals of indicators. The sixth indicator PO7 is identical to one proposed by the MORRI project, and the seventh only similar to another of the same project. In addition to the general results, AHP enables a more

in-depth discussion about the results, analysing the indicators for each relevant aspect. For the *Competence Building* aspect, the indicators considered most relevant are CB03 (21%) and CB07 (30%) (Fig. 9A). On the other hand, indicator CB01 can be considered irrelevant for any of the groups (Fig. 9B).

The administration group ii) clearly has a focus on the projects that have an educational purpose. The universities, research centre group i), prefers training for the researchers, and the researchers group highlights their preference for horizontal and vertical participation. All these figures confirm that the prioritization profile obtained for the stakeholders responds to their expectations.

Regarding Co-creation aspects, there is no indicator that clearly stands out from the rest, CO6, CO5, and CO1 being the most relevant ones Fig. 10A). In this case, the

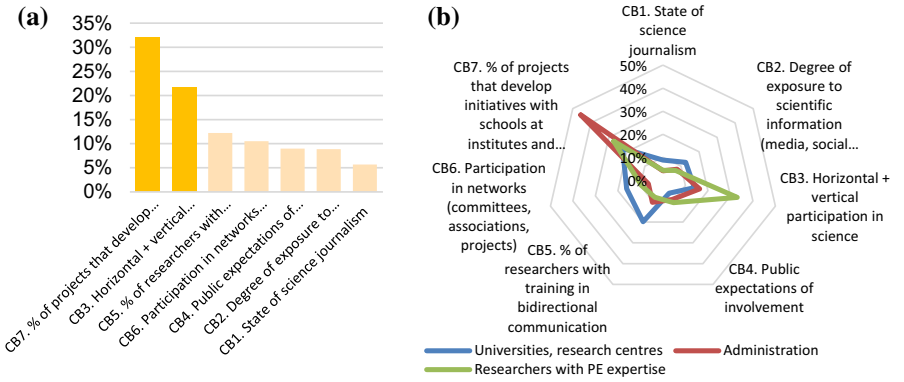


**Fig. 9** **a** Importance of competence building indicators. **b** Importance of competence building indicators by groups

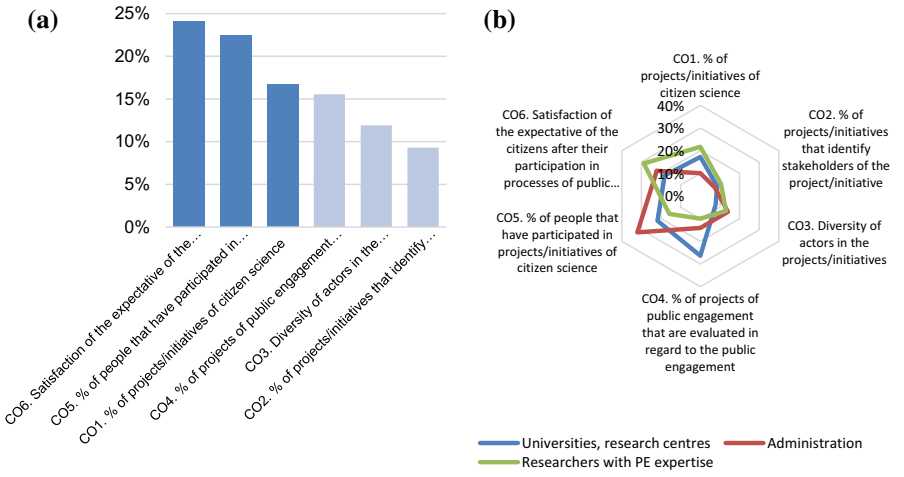


**Fig. 10** **a** Importance of co-creation indicators. **b** Importance of co-creation indicators by groups

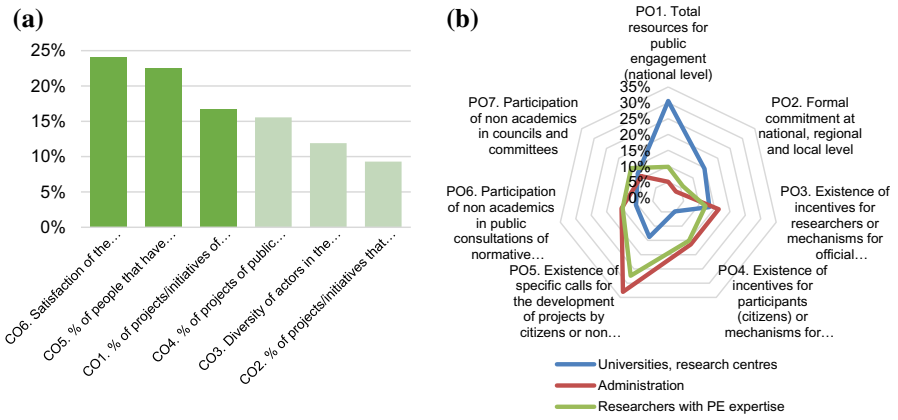


**Fig. 11** **a** Importance of Policy indicators. **b** Importance of policy indicators by groups

preference profiles for the three groups are more similar. However, the high importance that universities and research centres give to CO4 should be highlighted (Fig. 10B).

Regarding the Policy aspect, in Fig. 11B, we can see that stakeholders' groups ii) and iii) generally favour indicator PO5, and no other in particular. However, group i) favours PO1, and again no other indicator in particular. As a result, PO5 stands out on average, as previously discussed (Fig. 11). Hence, the need for a change in the calls is seen as very relevant for those who elaborate the proposals, and those who would benefit from it.

## 5 Conclusions

In this paper, the results of a participatory methodology used to define a list of RRI Public Engagement indicators generated by Spanish stakeholders for the Spanish scientific and innovation context are presented. The final list obtained could be used as a corner stone to operationalise the promotion of Public Engagement in a more Responsible Research and Innovation. That means to foster policy-making initiatives from an RRI perspective, and to enhance the co-creation with an effective participation of society in science. Such initiatives might be applied in the realm of the project, institutions and citizenship, which enable a wide variety of uses such as evaluation, learning, and comparison.

The aim of the present research has been answered. On the one hand, we have proposed a functional methodology that allows a participatory identification of the main aspects of the Public Engagement in S&T, and their indicators, for a particular context. Thus, we both put forward a method, we involve the main stakeholders, and we obtain context-based results, as demanded by other (Mejlgaard 2018; Stilgoe et al. 2013). The European indicators can be tailored to our national science and innovation policy context.

The Spanish panel of indicators is easy to manage by the scientific managers. It differs from the already existing European panels, since new context-based indicators appear, which suggests again new initiatives from an RRI perspective. Also, the new indicators are in line with the specificity of Spanish national science policy; the existing EU indicators may be too wide-ranging to be applied to a single country. They are more useful for comparisons among countries. Moreover, this new panel of indicators is more focused on the measurement of RRI initiatives at different levels of application, micro-level (projects, individuals) and macro-level (policies, programmes), in comparison with the already existing EU indicators. This suggests the need to open a debate about the PE perspective of the EU, because these new indicators could promote the debate if indicators such as *Existence of incentives for researchers or mechanisms for official recognition of the participation in processes of public engagement* could be considered contributions for the European RRI state-of-the-art rather than national particularities. To bring some light on these issues, further research in other European countries should be fostered.

To establish an order of relevance of these indicators, the AHP multi-criteria decision technique has been used. A trade-off is necessary between including as much importance (weight) as possible and keeping the list of elements simple. The approach based on a fixed cut-off 50% percentage has allowed to select the indicators in the most relevant positions. This way, the final set of indicators is easier to manage by the scientific managers.

Furthermore, another conclusion of our research is that we need to build on and continue the work instigated to ensure continuous data collection and further assessment and refinement of the PE indicators. This should lead to appropriate operationalisation of these indicators based on three objectives: aims, feasibility, and levels.

The technical efforts described in this paper need to be extended to allow a more complete understanding of the diverse and complex relationships between Public Engagement policies and practices and their societal, democratic, economic, and scientific benefits (AIMS).

These theoretical advances in combination with continuous data collection will inform the iterative learning processes needed to create a mature monitoring system with indicators and metrics that are robust, realistic, feasible, and easy to implement (FEASIBILITY).

Country-level monitoring allows national policy-makers to evaluate a country's position with respect to its targets, and other countries' performance. However, understanding the patterns and effects of policies requires a thorough understanding of organizational structures. In the context of monitoring, indicators are applied at a specific organizational level: national policies, organizations, research groups or projects, and individuals. The list of indicators produced during our research include different levels of aggregation, for example, public administration, universities and research centres, projects, and individuals. The distinction between micro-level (projects and individuals) and macro-level (public administration, research centres, universities) helps us to deal with the pressure between the effort to develop 'sophisticated indicators' and the need for simplicity and transparency to democratise science, as stated in responsible metrics approaches. These approaches recommend a focus on sophisticated indicators at the macro-level, because simple indicators often do not have the

required level of validity, and these indicators may, therefore, provide experts with a distorted world view (Waltman and van Eck 2018). However, simple indicators should be used in micro-level contexts, since they can reveal the relevant aspects. Besides an indicator that does not allow the expert to understand why it produces a particularly high or low ranking, would not be useful: "Keeping indicators simple ensures that experts can truly reflect on what indicators tell them and can take this into account in their expert assessment" (Waltman and van Eck 2018). (LEVELS).

There should be another debate on responsibilities related to monitoring and future policy-making based on these indicators, for example, to decide about social, scientific, and professional legitimacy that managers should have to measure and assess the results and to formulate new scientific policies (ROLES).

Finally, and regarding future developments of this research, we want to emphasize that the methodology proposed has the aim of being further generalized to broader contexts. Our next step will be to explore its application to the specific case of RRI and RIS3· (Regional Innovation Smart Specialization Strategies), which is a more regional-oriented approach.

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**Authors' contributions** The presented idea was conceived by García-Melón and Gómez-Navarro. Material preparation, data collection, and analysis were performed by García-Melón, Gonzalez-Urango, and Corona-Sobrino. The first draft of the manuscript was written by García-Melón and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Availability of data and materials** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

**Code availability** We have used a licensed software NVIVO-11 ® (NVP11-LZ000-BE02U-UY0D2-LG2RZ) and free software SUPERDECISIONS v. 2.10 ©

## References

Arrizabalaga I, Solans-Domènech M, Radó-Trilla N, Adam P (2016)How can we measure stakeholders' engagement in research? A literature review. In *Pers* (Issue 1)

Bauer MW, Allum N (2007) What can we learn from 25-years of PUS research ? Liberating and widening the agenda. Public Understand Sci 16(1)

Belton V, Stewart T (2002) Multiple criteria decision analysis: an integrated approach. https://books.google.com/books?hl=es&lr=&id=mxNsRnNkL1AC&pgis=1

Bertsch V, Hall M, Weinhardt C, Fichtner W (2016) Public acceptance and preferences related to renewable energy and grid expansion policy: empirical insights for Germany. Energy 114:465–477. https://doi.org/10.1016/J.ENERGY.2016.08.022

Bonner BL, Baumann MR, Dalal RS (2002) The effects of member expertise on group decision-making and performance. Org Behav Hum Decis Process 88(2):719–736. https://doi.org/10.1016/S0749-5978(02)00010-9

Chopyak J, Levesque P (2002) Public participation in science and technology decision making: trends for the future. Technol Soc 24(1–2):155–166. https://doi.org/10.1016/S0160-791X(01)00051-3

Commission E (2010) E u r o p e 2 0 2 0. A European strategy for smart, sustainable and inclusive growth

Cortiñas S (2009) Historia de la Divulgación Científica. Eumo Editorial

Cuevas A (2008) Conocimiento científico, ciudadanía y democracia. Revista Iberoamericana de Ciencia Tecnología y Sociedad, ISSN:1668–0030. https://www.redalyc.org/pdf/924/92441006.pdf

De Luca S (2014) Public engagement in strategic transportation planning: an analytic hierarchy process based approach Some of the authors of this publication are also working on these related projects: static assignment View project choice modelling View project Public engagement in strategic transportation planning: an analytic hierarchy process based approach. Elsevier. https://doi.org/10.1016/j.tranpol.2014.03.002

Dudo A, Besley JC (2016) Scientists' prioritization of communication objectives for public engagement. PLoS ONE 11(2):1–18. https://doi.org/10.1371/journal.pone.0148867

Durant J (1999) Participatory technology assessment and the democratic model of the public understanding of science. Sci Public Policy 26(5):313–319. https://doi.org/10.3152/147154399781782329

Jefatura del Estado (2011) Ley 14/2011, de 1 de junio, de la Ciencia, la Tecnología y la Innovación. Boletín Oficial Del Estado, 54387–54455. http://www.boe.es/boe/dias/2011/06/02/pdfs/BOE-A-2011-9617.pdf

Estévez RA, Walshe T, Burgman MA (2013) Capturing social impacts for decision-making: a multicriteria decision analysis perspective. Divers Distrib 19(5–6):608–616

García-Melón M, Pérez-Gladish B, Gómez-Navarro T, Mendez-Rodriguez P (2016) Assessing mutual funds' corporate social responsibility: a multistakeholder-AHP based methodology. Ann Oper Res. https://doi.org/10.1007/s10479-016-2132-5

Geoghegan-Quinn M, European Commission (2021) Responsible Research and Innovation. Europe's ability to respond to societal challenges. https://doi.org/10.2777/11739

Gläser J, Laudel G (2013) Life with and without coding: two methods for early stage data analysis in qualitative research aiming at causal explanations. Forum Qualit Soc Res Sozialforschung 14(2):1–25

Gregory R, Keeney RL (1994) Creating policy alternatives using stakeholder values. Manag Sci 40(8):1035–1038. https://doi.org/10.1287/mnsc.40.8.1035

Grimble R, systems KW-A (1997) Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities. *Elsevier*. Retrieved March 20, 2020, from https://www.sciencedirect.com/science/article/pii/S0308521X97000061

Gutrich J, Donovan D, Finucane M, W F.-J. of environmental (2005) undefined. (n.d.). Science in the public process of ecosystem management: lessons from Hawaii, Southeast Asia, Africa and the US Mainland. *Elsevier*. Retrieved March 20, 2020, from https://www.sciencedirect.com/science/article/pii/S0301479705000769

Haywood BK, Besley JC (2014) Education, outreach, and inclusive engagement: towards integrated indicators of successful program outcomes in participatory science. Public Underst Sci 23(1):92–106. https://doi.org/10.1177/0963662513494560

Diana H, Wouters P (2015) The Leiden Manifesto for research metrics. Use these ten principles to guide research evaluation. Nature 520(7548), 9–11. https://doi.org/10.1038/520429a

Higgs G, Berry R, Kidner D, Langford M (2008) Using IT approaches to promote public participation in renewable energy planning: Prospects and challenges. Land Use Policy 25(4):596–607. https://doi.org/10.1016/J.LANDUSEPOL.2007.12.001

Ignaccolo M, Inturri G, García-Melón M, Giuffrida N, Le Pira M, Torrisi V (2017) Combining analytic hierarchy process (AHP) with role-playing games for stakeholder engagement in complex transport decisions. Transp Res Procedia 27:500–507. https://doi.org/10.1016/J.TRPRO.2017.12.069

Ishizaka A, Labib A (2011) Review of the main developments in the analytic hierarchy process. Expert Syst Appl 38(11):14336–14345. https://doi.org/10.1016/j.eswa.2011.04.143

Joss S (1999) Public participation in science and technology policy- and decision- making - ephemeral phenomenon or lasting change? Sci Public Policy 26(5):290–293. https://doi.org/10.3152/147154399781782338

Kasemir B (2003) Public participation in sustainability science : a handbook. Cambridge University Press. https://books.google.es/books?hl=es&lr=&id=rZWVpU4yNQ4C&oi=fnd&pg=PR7&dq=kasemir+jaeguer+2003&ots=AyMGkONKHV&sig=a9pTH6KiT3AkdFhVac25-tjeyj0#v=onepage&q&f=false

Krejčí J, Stoklasa J (2018) Aggregation in the analytic hierarchy process: Why weighted geometric mean should be used instead of weighted arithmetic mean. Expert Syst Appl. https://doi.org/10.1016/j.eswa.2018.06.060

Krzywoszynska A, Matt W, Buckley A, Chiles P, Gregson N, Holmes H, Mawyin J (2018) Opening up the participation laboratory. Sci Technol Hum Values 43(5):785–809. https://doi.org/10.1177/0162243917752865

Lidinska L, Jablonsky J (2018) AHP model for performance evaluation of employees in a Czech management consulting company. CEJOR 26(1):239–258. https://doi.org/10.1007/s10100-017-0486-7

Ligardo-Herrera I, Gómez-Navarro T, Gonzalez-Urango H (2019) Application of the ANP to the prioritization of project stakeholders in the context of responsible research and innovation. CEJOR 27(3):679–701. https://doi.org/10.1007/s10100-018-0573-4

Ligardo-Herrera I, Gómez-Navarro T, Inigo EA, Blok V (2018) Addressing climate change in responsible research and innovation: recommendations for its operationalization. Sustainability (Switzerland), 10(6). https://doi.org/10.3390/su10062012

Macnaghten P, Owen R, Stilgoe J (2014) Responsible innovation across borders: tensions, paradoxes and possibilities. J Respons Innovat. https://doi.org/10.1080/23299460.2014.922249

Maleki H, Zahir S (2013) A comprehensive literature review of the rank reversal phenomenon in the analytic hierarchy process. J Multi-Criteria Decis Anal 20(3–4):141–155. https://doi.org/10.1002/mcda.1479

Meijer I, Mejlgaard N, Woolley R, Rafols I (2016) Monitoring the Evolution and Benefits of Responsible Research and Innovation (MoRRI)–a preliminary framework for RRI dimensions & indicators. https://digital.csic.es/handle/10261/161892

Mejlgaard N (2018) Science's disparate responsibilities: patterns across European countries. Public Underst Sci 27(3):262–275. https://doi.org/10.1177/0963662517724645

Monsonís-Payá I, García-Melón M, Lozano JF (2017) Indicators for responsible research and innovation: A methodological proposal for context-based weighting. Sustainability (Switzerland), 9(12). https://doi.org/10.3390/su9122168

Neresini F, Bucchi M (2011) Which indicators for the new public engagement activities? Public Understanding of Science, An exploratory study of European research institutions. https://doi.org/10.1177/0963662510388363

Otero-Hermida P, García-Melón M (2018) Gender equality indicators for research and innovation from a responsible perspective: The case of Spain. Sustainability (Switzerland), 10(9). https://doi.org/10.3390/su10092980

Peter V, Maier F, Mejlgaard N, Bloch C, Madsen EB, Griessler E, Wuketich M, Meijer I, Woolley R, Lindner R, Bührer S, Jäger A, Tsipouri L, Stilgoe J (2018) Monitoring the evolution and benefits of responsible research and innovation

Pira ML, Inturri G, Ignaccolo M, Research, AP-TU. (2015) Analysis of AHP methods and the Pairwise Majority Rule (PMR) for collective preference rankings of sustainable mobility solutions. Transp Res Procedia. https://www.sciencedirect.com/science/article/pii/S2352146515002185

Porter J, Williams C, Wainwright S, Cribb A (2012) On being a (modern) scientist: Risks of public engagement in the UK interspecies embryo debate. In New Genetics and Society (Vol 31, Issue 4, pp 408–423). Taylor & Francis. https://doi.org/10.1080/14636778.2012.687138

Ràfols I (2019) S&T indicators in the wild: contextualization and participation for responsible metrics. Res Evaluat 28(1):7–22. https://doi.org/10.1093/reseval/rvy030

Revuelta G (2013) Overview on Spanish National Policies towards responsible research and innovation. Res-AGorA MoRRI 1st Country Report Spain, 1–6

Saaty TL, Peniwati K (2008) Group decision making : drawing out and reconciling differences. RWS Publications

Saaty TL, Vargas LG (2007) Dispersion of group judgments. Math Comput Model 46(7–8):918–925. https://doi.org/10.1016/j.mcm.2007.03.004

Saaty TL (1980) The analytic hierarchy process: planning, priority setting, resources allocation. Mc. Graw Hill, New York

Saaty TL (1994) Fundamentals of decision making and priority theory with the Analytic Hierarchy Process (First Edit). RWS Publications

von Schomberg R (2012) Prospects for technology assessment in a framework of responsible research and innovation. *Technikfolgen Abschätzen Lehren: Bildungspotenziale Transdisziplinärer Methoden*. https://doi.org/10.1007/978-3-531-93468-6_2

Stilgoe J, Owen R, Macnaghten P (2013) Developing a framework for responsible innovation. Res Policy 42(9):1568–1580. https://doi.org/10.1016/j.respol.2013.05.008

Strand R, Spaapen J, Bauer MW, Hogan E, Revuelta G, Stagl S, Paula L, Guimaraes Pereira A (2015) Indicators for promoting and monitoring Responsible Research and Innovation - Report from the Expert Group on Policy Indicators for Responsible Research and Innovation. European Commission - Directorate-General for Research and Innovation

van Est R (2011) The Broad challenge of public engagement in science: Commentary on: "Constitutional Moments in Governing Science and Technology." Sci Eng Ethics 17(4):639–648. https://doi.org/10.1007/s11948-011-9296-9

Vargas L (1990) An overview of the analytic hierarchy process and its applications. Eur J Oper Res. http://www.academia.edu/download/49513733/0377-2217_2890_2990056-h20161010-6396-ygrbf4.pdf

Waltman L, van Eck NJ (2018) Field normalization of scientometric indicators. http://arXiv.org/abs/1801.09985

Wickson F, Carew AL (2014) Quality criteria and indicators for responsible research and innovation: learning from transdisciplinarity. J Respons Innovat 1(3):254–273. https://doi.org/10.1080/23299460.2014.963004