Invited Review

Operational Research for, with, and by citizens: An overview

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ABSTRACT

Interest in citizen participation is increasing generally. Almost all operational research (OR) is engaged with clients, but it is mainly in the areas of Soft and Community OR that wider stakeholder and citizen participation has been a significant focus. It is the involvement of citizens that is the subject of this paper. We surveyed OR literature and compiled a corpus of 62 studies, the earliest from 1970, to systematically characterize the involvement of citizens in OR processes. Our review produced three findings: First, some fields of OR have embraced citizen participation, but this is not yet a major concern outside the field of Community OR. Second, citizen participation in OR processes is often driven by a moral rationale. Third, progress in information and communication technology (ICT) enables broad participation, but traditional processes requiring physical presence can also be participatory. From these insights, we formulate research opportunities for OR. (1) OR may join Community OR's endeavor to engage with and empower citizens who have so far rarely been involved in OR processes. (2) OR may identify benefits and drawbacks of digital OR processes in empirical studies. (3) OR may determine whether involving large numbers of citizens is suitable for the societal scale. (4) OR may research building and maintaining trust. (5) OR may join efforts for data protection of participants. (6) OR may systematically report and reflect on participatory OR processes. (7) OR should continue researching the fair aggregation of individual inputs. Citizen participation in OR is topical and challenging. Pursuing these research opportunities will contribute to OR fulfilling its mandate of better decision-making in close cooperation with all affected stakeholders.

1. Introduction

Operational research (OR, operations research in American English) aims at offering "a scientific approach to the solution of problems in the management of complex systems. [It] has been used intensively in business, industry and government … to find practical and pragmatic solutions to operational or strategic problems. … OR in practice is a team effort, requiring close cooperation among the decision-makers, the skilled OR analyst and the people who will be affected by the management action" (webpage "what is Operational Research?" from EURO the Association of European Operational Research Societies, retrieved on Nov. 2020). In essence, OR can support participatory, sometimes public, decision-making. However, it is frequently unclear who the "people who will be affected" are. As an illustration, one recent review of the role of stakeholders in OR does not define the term stakeholder (de Gooyert et al., 2017). Knowing who the affected stakeholders are is important, because it influences the OR methods used and the communication of the project (Cockerill et al., 2019; Gregory et al., 2020; Reed et al., 2018).

A stakeholder is "one who is involved in or affected by a course of action" (Merriam-Webster, retrieved on Oct. 2021). Originally, the word stakeholder was created in the field of business ethics and organizational management to emphasize that companies should create value not only for the stockholders or shareholders, but for all involved and interconnected persons having a stake in the organization, e.g., employees, customers, or suppliers (Freeman 2010). de Gooyert et al. (2017) provide background on the historical development of the concept, and the major issues in stakeholder theory. Within this field, visions of the authors differ on three main dimensions summarized in Fig. 1. Contrarily to the original definition centered on the object of a firm, here, we use the term stakeholder for "any group or individual who can affect or is affected by the achievement of [a defined overarching objective]" (adapted from Freeman 2010, p.46). In case of a public or governmental decision, or of problems involving societal or environmental dimensions, which can raise strong emotional reactions, the term stakeholder can be quite encompassing. It can certainly include citizens,

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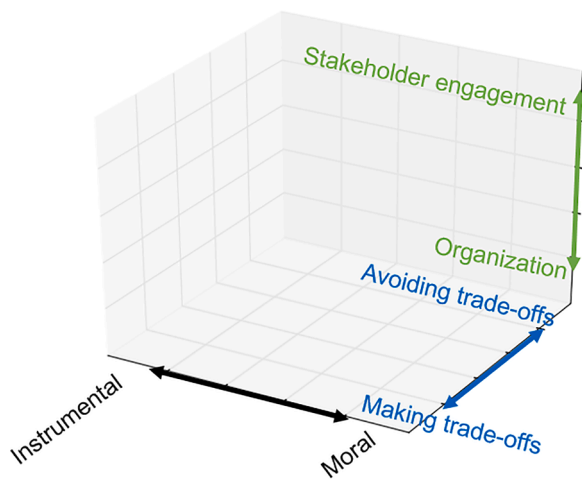 *E-mail address:* aube@zhaw.ch (A.H. Aubert).

Fig. 1. Three divergent views in the field of stakeholder theory. Summary of the findings of de Gooyert et al. (2017).

defined as inhabitants of a city or town, or members of a state that have the rights, privileges, and civil and political duties of free members of that society (combined definitions from Larousse 2020; Merriam-Webster 2020). In general, a stakeholder can be any individual *affected* by the decision. Thus, we understand stakeholder as a term broader than interest groups who have a representative mandate.

Citizen participation is topical in many areas: a search for the terms "citizen" AND "participat*" in Web of Science returned over 18,500 results (on 10.07.2020) (SI1.1). We were interested in understanding the participation of citizens in OR; by which we mean the participation of individuals who are usually under-represented in decision-making, such as inhabitants without a representative mandate. In this article, we identify the state-of-the-art in the OR literature using the word 'citizen', and widened it to encompass the Community OR (COR) literature, which deals with "meaningful engagement with communities" (Midgley et al. 2018, p.771). About four decades ago, there was a pioneering 'Custom and Practice' call of the president of the UK OR society, Jonathan Rosenhead, to develop more participatory OR (Rosenhead 1986). Actually, this call itself came "half a generation" after Steve Cook suggested consumer groups or resident associations as "potential sponsors" of OR (Rosenhead 1986, p.337). After decades, we are thus interested to capture developments, and our first research question is: What is the status of citizens in OR? Are citizens among the stakeholders considered by OR?

Citizen participation is desirable for several reasons. First, citizen participation is sometimes a legal requirement (e.g., BAFU 2019). Second, a moral rationale may impose an ethical duty to involve all affected citizens democratically in public decisions (Brauer 2018; de Gooyert et al. 2017; Lavin and Rios Insua 2010; Ulrich 1994). Third, it can provide a means of legitimizing decisions and implementing decisions smoothly: i.e., it can have an instrumental rationale (de Gooyert et al. 2017; Lavin and Rios Insua 2010). Two democracy paradigms are reported in the literature: a deliberative democracy paradigm and a participatory one (Papadopoulos and Warin 2007). In the deliberative paradigm, representatives of the various interest groups obtain a deep understanding of the problem at stake. This paradigm aims at increasing the depth of participation (Gregory et al. 2016). In the participatory paradigm, the main aim is to increase the breadth of participation: as many citizens as possible should participate (Gregory et al. 2016). Hence, our second research question is: Why do citizens participate in OR processes? What drives OR studies focusing on citizens?

Citizen participation is challenging because citizens are numerous and do not constitute a homogeneous group (BAFU 2019; Rios Insua et al. 2010). Groups of citizens are often multi-nodal and heterogeneous

organizations (as opposed to uninodal and homogeneous, i.e., pyramidal and hierarchical) (Rosenhead 1986). Citizen participation requires specifically-designed participatory processes and methods (Reed et al. 2018). This need for appropriate OR methods was also part of Rosenhead's call 'Custom and Practice' (Rosenhead 1986; Rosenhead 1989). Almost four decades later, our third research question proposes to observe where we stand: How do citizens participate in OR projects? What factors enable citizen participation in OR processes?

We reviewed the published OR literature since 1970 to answer our three research questions. We explain the creation of the corpus in Section 2, and the systematic classification. We present our results in Section 3. We synthesize the answers to our research questions in Section 4, and summarize themes to which OR researchers should attend when dealing with citizen participation.

2. Methods

We first conducted a preliminary general search, which showed that citizen participation in decision-making is topical (SI1.1). Thereafter, we refined our search strategy to target the OR literature. We carried out three complementary searches in Web of Science (WOS). The first search, guided by Research Question 1 (RQ1), aimed to determine whether "citizens" are among the stakeholders considered by OR. The second search complemented the corpus to address RQ2 and RQ3, by identifying drivers for and enablers of the involvement of citizens in OR. These two searches resulted in a corpus comprising 39 articles (Fig. 2). After analyzing this initial corpus, it became obvious that it lacked essential work that has been carried out by Community (based) OR (COR) over five decades. We thus added an additional 23 important articles from COR to the corpus. We give details of the search strategies below.

First, in March 2020, we searched for the term "citizen" in the title, abstract, and keywords in 27 OR, management, and decision journals (Tab.SI1-2, SI1.2). The timespan included all years. We searched these indexed databases: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC. For two journals, *OR Insight* and *INFOR: information systems and operational research*, which are not indexed in those databases, we searched for the word "citizen" in the publisher search engine. This search led to 76 articles (Fig. 2). We used the titles and abstracts to classify the articles into three main categories: conceptual, such as a review or position paper; empirical, such as a case study or experiment; and mixed. We read all 76 abstracts, and in case of uncertainty read through the full text to select those articles that actually concerned citizen participation in democratic and governmental processes and decision-making. We identified the articles that included these terms: "value," "preference," "opinion," "worldview," "perspective," which are various terms corresponding to citizens' opinions, "govern*," or "democra*" (Tab.SI1-3, SI1.3). The review protocol is available in the Supplementary Information. This resulted in 29 articles, which we read in depth.

Second, in August 2020, we searched for combinations of the topic "operation* research" with one of the following other topics: "participat*," "stakeholder," "public," "population," or "democra*." We did so for all timespans, and in the same databases as were used in the first search (Fig. 2). We screened the 1,552 results, and kept the 371 papers published in the same OR journals as in the first search. After removing duplicates, we read the remaining 295 abstracts. We selected empirical papers about broad citizen participation to complement citizen participation in which a few citizens represent an interest group, which was well covered in the first search. We aimed to identify those papers reporting approaches that differ from onsite group decision and negotiations. This increased our corpus with six conceptual and four empirical articles (Fig. 2).

Finally, in August 2022, we used WOS for a search in the same time span as the first search. We searched in the journals EJOR and Omega for articles containing the keywords "Community operation* research",
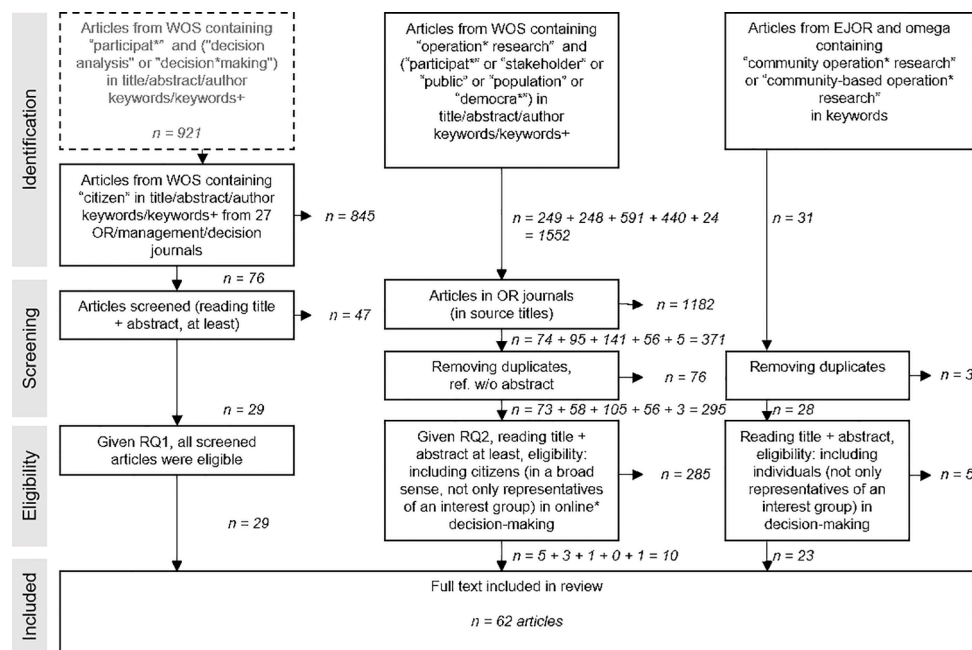
Fig. 2. Flow diagram of the corpus constitution, following Preferred Reporting Items for Systematic Reviews and Meta-Analysis (Page et al. 2021). We used three searches in Web of Science (WOS) to answer the research questions (RQ).

"Community-based operation* research" or "Community based operation* research". This resulted in 31 papers, of which three were already part of the corpus. We selected the 23 articles concerned with the participation of individuals. We aimed at better acknowledging the large contribution that Community OR and Community-based OR (Johnson 2012) has made in the field of meaningful engagement with communities, a phrase that was coined by Midgley et al. (2018). We are aware that this process cannot provide a comprehensive overview of the rich COR literature. However, we are confident that we were able to capture important literature, which allows us to provide an insight into this stream of OR.

We used 14 characteristics to identify the main features of the full corpus of these 62 articles (Table 1; full table see SI). Again, while not being exhaustive, our corpus should provide an exemplary sample of the literature. This classification enabled us to define OR studies focusing on citizens or individuals engaged in decision-making (RQ1), and identify main drivers (RQ2) and enablers (RQ3) of such participation in OR processes. While reading the full texts, we also identified and classified research gaps and aspects that deserve particular attention.

3. Results: Citizens in OR

3.1. Overview of the article selection

Our selection led to 62 articles, of which 21 are conceptual, 32 empirical, and 9 mixed. These articles have appeared in 13 journals, including the major OR journals, as defined by de Gooyert et al. (2017). The oldest paper was from 1970, and the most recent papers from 2019. Our corpus thus covers nearly 50 years. Half of the papers (33) are qualitative OR and 14 quantitative, the other 15 being a mix. We are aware that our sample is far from exhaustive. However, because our selection was very diverse and included conceptual and empirical references for both quantitative and qualitative OR types, our sample should illustrate a good share of the variety of existing OR approaches interested in citizens. Here, we summarize who these citizens are, why OR is interested in citizens, how this interest translates into the practice of OR, and in which contexts.

3.2. Who are the citizens?

The texts in our corpus defined citizens as users, end-users, people, lay people, individuals, stakeholders, participants, interest groups, the general public, the wider public, communities and community members, active citizens, ordinary citizens, lay citizens, savvy citizens, smart people, atomized citizens, clients, digitally empowered consumers, consumers, service consumers in a government–citizen context, co-producers of public services, citizen scientists, women, younger adults, senior citizens, veterans, local people, residents, indigenous people, and underprivileged citizens. From our corpus, citizens are both very numerous and very diverse, for instance in terms of background and education. Most papers from COR specifically focused on marginalized communities (e.g., Burns 2018; Gomes et al. 2018; Herron and Mendiwelso-Bendek 2018; Mwiti and Goulding 2018; Pinzon-Salcedo and Torres-Cuello 2018; Taket and White 1994; White and Taket 1997), disadvantaged populations (e.g., Ackoff 1970; Kaplan 2008; Morgan and Fa`aui 2018; Wang et al. 2018; Yearworth and White 2018), or underrepresented persons (e.g., Ferretti and Gandino 2018; McKenna et al. 2018). This indicates that some streams of OR have become increasingly interested in a diversity of citizens, without an age limit (from younger adults to the elderly). OR can also support the inclusion of underprivileged citizens.

The papers differed in whether they focused on citizens as individuals or groups (Table 2). Twenty-one publications targeted groups. These groups involved at least 11 citizens (Hjortso 2004), and at most 200 citizens (Goulding et al. 2018; O'Brien and Meadows 2007). Thirteen papers, including eight conceptual papers, did not specify the number of participants (Brocklesby and Beall 2018; de Gooyert et al. 2017; Helfgott 2018; Herron and Bendek 2007; Herron and Mendiwelso-Bendek 2018; Hipel et al. 2008; Kunsch et al. 2009; Li and Zhu 2014; Marttunen et al. 2017; Midgley and Ochoa-Arias 1999; Morgan and Fa`aui 2018; Okada et al. 2013; Tavella and Papadopoulos 2017).

The smaller groups comprised representatives of diverse interest groups, such as a local recreational interest group, a national environmental interest group, school administrative staff, and local inhabitants. They also included the problem owners, such as a municipality, or the sponsor of the decision-making process, such as the county or

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Table 1

Characteristics used to structure our literature review, categories used, if relevant, and reference to published work using these characteristics and categories.

Characteristics	Categories (if relevant)	Original reference
1. Who? Exact wording for the targeted "citizen"	NA (words used)	Specific to answer RQ1
2. Who? Participation setting	Three possible: groups, individuals, or both	Specific to answer RQ1
3. Who? Exact number of participants	NA (number reported)	Specific to answer RQ1
4. Where? Scale of the participatory process	Three possible: micro (local), meso (organization), macro (society)	French et al. (2005)
5. Where? Country where the empirical study took place	NA (country of empirical study)	General characteristic
6. When? Year published	NA (year)	General characteristic
7. What? Type of OR study	Three possible: qualitative OR, quantitative OR, or both	de Gooyert et al. (2017)
8. What? Topic of application	NA (e.g., disaster resilience, user satisfaction, public service delivery, etc.)	General characteristic
9. Why? Motivation for citizen participation	Three possible: predominantly instrumental, predominantly moral, or both	de Gooyert et al. (2017); Brauer (2018)
10. Why? Aim of participation	Three possible: informing (public communication), consulting (consultation), co-deciding (participation), or combinations of these	Arnstein (1969); de Gooyert et al. (2017); Rowe and Frewer (2005)
11. Why? Aim of participation (paradigm)	Three possible: breadth, depth, or both	Gregory et al. (2016); Papadopoulos and Warin (2007)
12. How? OR method	If specified (e.g., problem-structuring method, decision support systems, etc.)	Specific to answer RQ3
13. How? Associated tools	If specified (means of citizen participation such as interview, group workshop, online survey, civic technology)	Specific to answer RQ3
14. How? OR tradition	Five possible: optimizing, balancing, structuring, involving, or combinations of these, and decision support systems	Adapted from de Gooyert et al. (2017)

governmental agency funding or initiating the process. Thus, both representatives with decision-making power and those being affected by the outcome of the participatory process were engaged. In these groups, most participating citizens had a specific representative mandate, such as political representative or association representative. An exception is the case of Community OR. The larger groups, those above 70 participants, were obviously more inclusive of citizens that did not have a representative mandate.

Community OR projects distinguished themselves as being more inclusive. There, groups were commonly composed of individuals without any representative mandate but qualifying as members of the community (e.g., Herron and Mendiwelso-Bendek 2018), of an ethnic group (e.g., Brocklesby and Beall 2018), or of a self-organized or grass-root organization (e.g., Espinosa and Walker 2013). These groups gathered from about 30 up to around 80 persons (e.g., Espinosa and Duque 2018; Taylor 2018).

The majority (13 of 21) of all the publications that included groups addressed a local issue at the community, district, or city level (micro-scale; Table 2) (e.g., Goulding et al. 2018; Herron and Bendek 2007; Hjortso 2004; Konsti-Laakso and Rantala 2018; Okada et al. 2013). One focused on the mesoscale (O'Brien and Meadows 2007), and two on the macroscale (Fitzgerald et al. 2016; Hipel et al. 2008). Groups can be

inclusive and gather many citizens, in some cases up to 200. In these cases, the tools used were accessible to many, including methods from the arts, such as theater performances and handcrafting (Goulding et al. 2018), or rich pictures incorporated in a mixed methodology process (e.g., Brocklesby and Beall 2018; Espinosa and Duque 2018).

We classified 23 publications as targeting individuals (Table 2). The reported number of participants varied from 71, in which case they had a representative mandate (Haag et al. 2019), to tens of thousands without a representative mandate (e.g., Mateos et al. 2015). Some Community OR projects physically involved up to 100 participants at the local, city, or community level (e.g., Ferretti and Gandino 2018; Yamori 2012; Yearworth and White 2018). One project involved 300 underprivileged citizens in rural India in semi-structured interviews to inform a multicriteria decision analysis (MCDA) project (Grover et al. 2019). The highest number of citizens considered was 87,899 (Durbach and Montibeller 2019). In this case, the citizens were actually consumers of online betting platforms, and the OR researchers studied behaviors by retrieving large datasets and applying data analytics methods. These citizens were not aware that they contributed to a behavioral OR study. Whether this type of approach, where citizens are not aware of their role as participants, really addresses citizen participation is open to discussion. All cases involving from hundreds to several thousands of citizens used civic technology (e.g., Chen et al. 2016; Lee and Rao 2009; Li and Gregor 2011; Mateos et al. 2015; Osman et al. 2019), online interfaces (Cabrera et al. 2018; Kassen 2018), social media (Yearworth and White 2018), or big data (de Witte and Geys 2013; Pala and Zhuang 2019; Power 2016). Civic technology includes information and communication technologies (ICT) for engagement of citizens and/or exchange between citizens and their governing bodies (Bwalya and Mutula 2014). We identified various types of civic technology use in OR (Section 3.7). Studies focusing on individuals often included more participants than those focusing on groups, although some groups were as large as or larger than some studies focusing on individuals, particularly in Community OR work.

3.3. Why do OR processes deal with citizens?

We classified the 62 articles according to three distinctions found in literature. The first is derived from stakeholder theory. It specified whether the rationale for participation was *predominantly* moral, an intrinsic value per se, or *predominantly* instrumental with returns expected (de Gooyert et al. 2017). A moral rationale means that citizen participation ought to happen in democratic processes: citizen participation is inherent to any public decision-making process, including those that are supported by OR. An instrumental rationale means that citizen participation is carried out to fulfil another goal, such as smooth implementation of a decision. Thirty-two papers were mainly motivated by instrumental reasons (Table 3), 26 mainly by moral reasons, and four discussed both (de Gooyert et al. 2017; Kunsch et al. 2009; Lourenco and Costa 2007; Parry and Mingers 1991). Half of the conceptual papers advocated moral rationales for citizen participation (11 of 21, plus four discussing both rationales), and most empirical papers advocated instrumental rationales (21 of 32). These results, based on our non-exhaustive corpus, could indicate that general reflections on citizen participation incorporated moral and ethical considerations, while engaging citizens in concrete participatory OR processes seemed mainly instrumental. We emphasize further that being predominantly motivated by one rationale is not excluding a share of the other rationale (e.g., Espinosa and Duque 2018; Morgan and Fa`aui 2018). Specifically, papers on the use of boundary critique in participatory projects are an exception to our observation: these are generally practice papers that do consider the moral rationale, and only some the instrumental rationale as well (e.g., Foote et al. 2021; Helfgott et al. 2023; Ufua et al. 2018).

Second, we distinguished whether the aim was mainly to increase the breadth or the depth of participation (Gregory et al. 2016). Increasing the breadth of participation means involving as many people as possible

Table 2

Citizens in OR processes as individuals or as groups per scale of the process. Emp: empirical paper; Co: conceptual paper; Mix: both empirical and conceptual. Numbers in bold in parenthesis are the reported number of participants. For the microscale other than Community OR, we specify in parenthesis the geographical scale. Note, for readability of the table, the papers are referred to with solely the first author's name and the year.

Citizens as → Scale ↓	Individuals	Groups	Not specified	Both individuals and groups
Micro (local)	Emp: Grover 2019 (**300**, villages) Yamori 2012 (**150**) Haag 2019 (**71**, region) Kassen 2018 (city) Ortiz 2010 (city) Ferretti 2018 (**100**, city) Yearworth 2018 (region) Sommer 2016 Co: Lourenco 2007 (city) Gomez 2016 (city) Mix: Rios 2008 (city) Walczak 2017 (city)	Emp: Brocklesby 2018 Espinosa 2018 (**80**) Goulding 2018 (**200**) Hjortso 2004 (**11**, district), Konsti-Laakso 2018 (**70**, city) McKenna 2018 (**19**) Morgan 2018 Tavella 2017 Taylor 2018 (**29**) Co: Herron 2007 Okada 2013 Midgley 1999 Mix: Herron 2018	Co: Bayley 2008 Gregory 2018 Parry 1991 Mix: Mustajoki 2000 (region) de Witte 2013 (city)	Emp: Cabrera 2018 (**455**) Espinosa 2013 (**37**) Mwiti 2018 (**25**) Pinzon-Salcedo 2018 (>**745**) Wang 2018 (**30**) White 1997 White 2007 (city) Co: Ackoff 1970 Mix: Gomes 2018 (**90**) Taket 1994
Meso (organization)	Emp: Siskos 2014 Co: Carton 2016	Emp: O'Brien 2007 (**200**)	-	-
Macro (society)	Emp: Chen 2016 (**449**) Lee 2009 (**150**) Li 2011 (**128**) Osman 2019 (**3,178**) Co: Mateos 2015 (**10,000**) Pala 2019 Power 2016	Emp: Fitzgerld 2016 (**25**) Co: Hipel 2008	-	-
Not specified	Emp: Siskos 2014 Co: Stevens 1970 Mix: Durbach 2019 (**87,899, 12,000, 87,603**)	Co: de Gooyert 2017 Li 2014 Marttunen 2017 Kunsch 2009 Mix: Helfgott 2018	Co: Benyoucef and Verrons, 2008	Emp: Burns 2018 (>**70**) Co: Kaplan 2008

in a participatory democracy paradigm (Arenilla 2010; Lavin and Rios Insua 2010; Papadopoulos and Warin 2007). Increasing the depth of participation means in-depth understanding of and engagement with the problem at stake. This corresponds to a deliberative democracy paradigm (Lavin and Rios Insua 2010; Papadopoulos and Warin 2007). Twenty papers focused on increasing the breadth of participation, 23 the depth, and 19 reported targeting both depth and breadth (Table 3). Of the 20 papers aiming at increasing breadth, 11 belonged to quantitative OR and were based on ICT or big data. Seventeen of the papers that aimed to increase the depth belonged to qualitative OR. Thus, the following trends were observed: increasing the depth mostly occurred in qualitative OR, whereas increasing the breadth occurred for both OR types, and if increasing the breadth was done in quantitative OR, it relied on ICT and big data.

Third, we used a simplified version of Arnstein (1969) ladder of participation (de Gooyert et al. 2017; Green and Hunton-Clarke 2003; Rowe and Frewer 2005) to identify three types of goals for stakeholder participation: informing, consulting, and co-deciding. Informing is when the decision-maker provides contextual information to the citizens in a top-down way: citizens are informed about the options, their rights, and obligations, but no feedback, comment, or negotiation is taking place. Consulting is when the decision-makers organize bottom-up communication platforms to collect opinions from the citizens (e.g., with surveys); however there is no guarantee that the collected information will be used because the citizens are not part of the final decision. According to Arnstein's ladder, informing and consulting are forms of tokenism (Arnstein 1969). Co-deciding encompasses forms of participation where two-directional exchanges are actually taking place: exchanges from the decision-makers to the citizens and from the citizens to the decision-makers are both influencing the decision process. We coded three papers as solely informing (Kaplan 2008; Ortiz-Fournier et al. 2010; Osman et al. 2019), seven as solely consulting (Fig. 3), and 19 as solely co-deciding. Twenty-four co-deciding papers also included either informing, or consulting, or both (Fig. 3). Nine papers focused on informing and consulting (Fig. 3). Most papers that used consulting, and both consulting and informing, aimed to increase the breadth of

participation (references in italics in Fig. 3) or the breadth and depth (references in bold italics in Fig. 3). Most papers aiming at co-deciding increased the depth of participation, or both the depth and breadth (Fig. 3).

The classification frameworks concerning the purpose of citizen participation supported and complemented each other. Citizens were involved in OR processes for either an instrumental or moral rationale. Citizen involvement aimed at increasing either the breadth of participation by including more individuals, or the depth by increasing the understanding of a problem, or a combination of both. The goal was to inform, consult, co-decide, or a combination of these.

3.4. How does the interest in citizens translate to the practice of OR?

We coded the papers into one of four OR traditions (de Gooyert et al. 2017): optimizing, balancing, structuring, and involving. In the optimizing tradition, stakeholders perceive a known current situation homogeneously and have a known and shared goal, and the desired outcome is to implement an optimal solution. Five papers focused mainly on optimizing (de Witte and Geys 2013; Grover et al. 2019; Kaplan 2008; Osman et al. 2019; Pala and Zhuang 2019). They used surveys, ICT, and big data, and they focused on increasing the breadth of participation. Kaplan (2008) proposed using optimization modelling techniques to serve under-privileged individuals and communities.

In the balancing tradition, stakeholders perceive a known situation homogeneously and have a shared, partially unknown goal, and the desired outcome is to compromise between conflicting goals (de Gooyert et al. 2017). Four papers focused mainly on balancing (Gomez et al. 2016; Mateos et al. 2015; Rios and Insua 2008; Walczak and Rutkowska 2017). All four papers belonged to the quantitative OR type, used ICT tools, and aimed to increase the breadth of participation. They concerned participatory budget allocations, in which citizens voted to express how they would allocate a budget at the microscale (city) (Gomez et al. 2016; Rios and Insua 2008; Walczak and Rutkowska 2017), or beyond (Mateos et al. 2015).

In the structuring tradition, as defined by de Gooyert et al. (2017),

Table 3
Motivations for including citizens in OR processes. Qnt: quantitative type of OR; Qly: qualitative type of OR; QQ: both quantitative and qualitative.

Rationale → Aim ↓	Mainly moral	Mainly instrumental	Both
Increasing depth (deliberative paradigm)	Qly: Brocklesby and Beall (2018); Espinosa and Duque (2018); Herron and Bendek (2007); Li and Zhu (2014); Midgley and Ochoa-Arias (1999); Mwiti and Goulding (2018); Taket and White (1994); Tavella and Papadopoulos (2017)	Qnt: Haag et al. (2019); Kaplan (2008) Qly: Ackoff (1970); Cabrera et al. (2018); Fitzgerald et al. (2016); Gomes et al. (2018); Hjortso (2004); Ortiz-Fournier et al. (2010); O'Brien and Meadows (2007); Sommer and Mabin (2016); Wang et al. (2018) QQ: Hipel et al. (2008); Marttunen et al. (2017); Taylor (2018)	QQ: Kunsch et al. (2009)
Increasing breadth (participatory paradigm)	Qnt: Mateos et al. (2015); Rios and Insua (2008) Qly: Kassen (2018); Stevens (1970); White and Taket (1997); Yamori (2012) QQ: Carton (2016); Pala and Zhuang (2019); Power (2016)	Qnt: Chen et al. (2016); Durbach and Montibeller (2019); Lee and Rao (2009); Li and Gregor (2011); Osman et al. (2019); Siskos et al. (2014); Walczak and Rutkowska (2017); de Witte and Geys (2013); Gomez et al. (2016) QQ: Grover et al. (2019); Yearworth and White (2018)	-
Both	Qly: Burns (2018); Goulding et al. (2018); Gregory and Atkins (2018); Helfgott (2018); Herron and Mendiwelso-Bendek (2018); Okada et al. (2013); White and Bourne (2007) QQ: Bayley and French (2008); Morgan and Fa`aui (2018)	Qnt: Mustajoki and Hämäläinen (2000) Qly: Benyoucef and Verrons (2008); Espinosa and Walker (2013); Konsti-Laakso and Rantala (2018) QQ: Ferretti and Gandino (2018); McKenna et al. (2018); Pinzon-Salcedo and Torres-Cuello (2018)	Qly: Lourenco and Costa (2007) QQ: de Gooyert et al. (2017); Parry and Mingers (1991)

stakeholders perceive the current situation incompletely or perceive it idiosyncratically: each in their own special way. They have a shared, partially unknown goal, and the desired outcomes are to clarify issues and actions to create commitment to those actions (de Gooyert et al. 2017). Seventeen papers focused mainly on structuring (Brocklesby and Beall 2018; Espinosa and Walker 2013; Ferretti and Gandino 2018; Fitzgerald et al. 2016; Goulding et al. 2018; Haag et al. 2019; Helfgott 2018; Lourenco and Costa 2007; McKenna et al. 2018; Mwiti and Goulding 2018; O'Brien and Meadows 2007; Okada et al. 2013; Ortiz-Fournier et al. 2010; Taylor 2018; Wang et al. 2018; Yamori 2012; Yearworth and White 2018). Various methods and tools were used, often in mixed methodology approaches, but all papers except one (Haag et al. 2019) displayed a qualitative component.

In the involving tradition, stakeholders perceive the current situation

incompletely or idiosyncratically, they have conflicting goals, and the desired outcomes are to manage those conflicts without necessarily aiming at consensus and to create commitment to actions (de Gooyert et al. 2017). Eight papers were classified in this category (Ackoff 1970; Gomes et al. 2018; Li and Zhu 2014; Morgan and Fa`aui 2018; Pinzon-Salcedo and Torres-Cuello 2018; Sommer and Mabin 2016; White and Bourne 2007; White and Taket 1997). The empirical studies used a problem-structuring method, such as the strategic choice approach, critical systems heuristics, soft systems methodologies, or a combination of these and other methods.

We added a fifth OR tradition not listed in de Gooyert et al.'s (2017) classification of supporting systems. This comprised the OR work that uses decision support systems to help governments exchange with, provide services to, and inform many citizens about decisions in the most transparent way. These eight papers focused on developing or assessing interfaces or ICT tools linking governments and citizens. Among these eight papers (Carton et al. 2016; Chen et al. 2016; Kassen 2018; Lee and Rao 2009; Li and Gregor 2011; Power 2016; Siskos et al. 2014; Stevens 1970), only Stevens (1970) did not concern a digital interface, because such technology was largely unavailable when it was written. This paper is discussed in Section 3.6.

The type of OR is related to the methods and tools used for interacting with the citizens. Among the nineteen empirical qualitative OR papers, we identified these methods and tools: facilitated workshops using visual imagery (Fitzgerald et al. 2016), collaborative artistic activities (Goulding et al. 2018), games and town walks (Yamori 2012), and often problem-structuring methods, such as strategic option development and analysis and the strategic choice approach, with interviews, cognitive mapping, concept mapping workshops, and public conferences (e.g., Brocklesby and Beall 2018; Hjortso 2004; Konsti-Laakso and Rantala 2018; O'Brien and Meadows 2007; White and Bourne 2007; White and Taket 1997). In some cases, this was combined with the Delphi method (e.g., Ortiz-Fournier et al. 2010). Often, mixed methodologies, also referred to as methodological pluralism, were used (e.g., Burns 2018; Cabrera et al. 2018; Espinosa and Duque 2018; Espinosa and Walker 2013; Sommer and Mabin 2016; Wang et al. 2018). One paper discussed web interfaces (Kassen 2018).

The conceptual papers in the qualitative OR type were also based on such methods: problem-structuring methods, critical systems practice, systemic intervention, action research (Ackoff 1970; Gregory and Atkins 2018; Li and Zhu 2014; Midgley and Ochoa-Arias 1999), and active learning for active citizenship (Herron and Bendek 2007), which required face-to-face activities such as workshops, interviews, and community activities (Okada et al. 2013; Stevens 1970). Two conceptual papers suggested using a digital tool for this type of method, one an interface developed for collaborative writing (Lourenco and Costa 2007), and the other e-negotiation protocols (Benyoucef and Verrons 2008).

Among the empirical and mixed quantitative OR papers, MCDA and value-focused thinking were used with multiattribute value theory (MAVT), the analytic hierarchy process (AHP) (Grover et al. 2019; Haag et al. 2019; Mustajoki and Hämäläinen 2000), or UTA and MIIDAS (Siskos et al. 2014). Of the other seven papers, one focused on behavioral analytics with data mining (Durbach and Montibeller 2019), or other big data (de Witte and Geys 2013), and four assessed decision support systems with the aim of improving them (Chen et al. 2016; Lee and Rao 2009; Li and Gregor 2011; Osman et al. 2019). Two papers proposed aggregation and optimization methods for participatory budgets (Rios and Insua 2008; Walczak and Rutkowska 2017), such as TOPSIS, which includes fuzzy techniques. The conceptual, quantitative OR papers also proposed aggregation optimization methods for participatory budgets with either a belief decision matrix and Dempster-Shafer theory (Mateos et al. 2015), stochastic programming (Gomez et al. 2016), or different optimization modelling (Kaplan 2008).

As a result, two types of tools clearly emerged. Some tools required physical presence: OR interactions with face-to-face interviews and
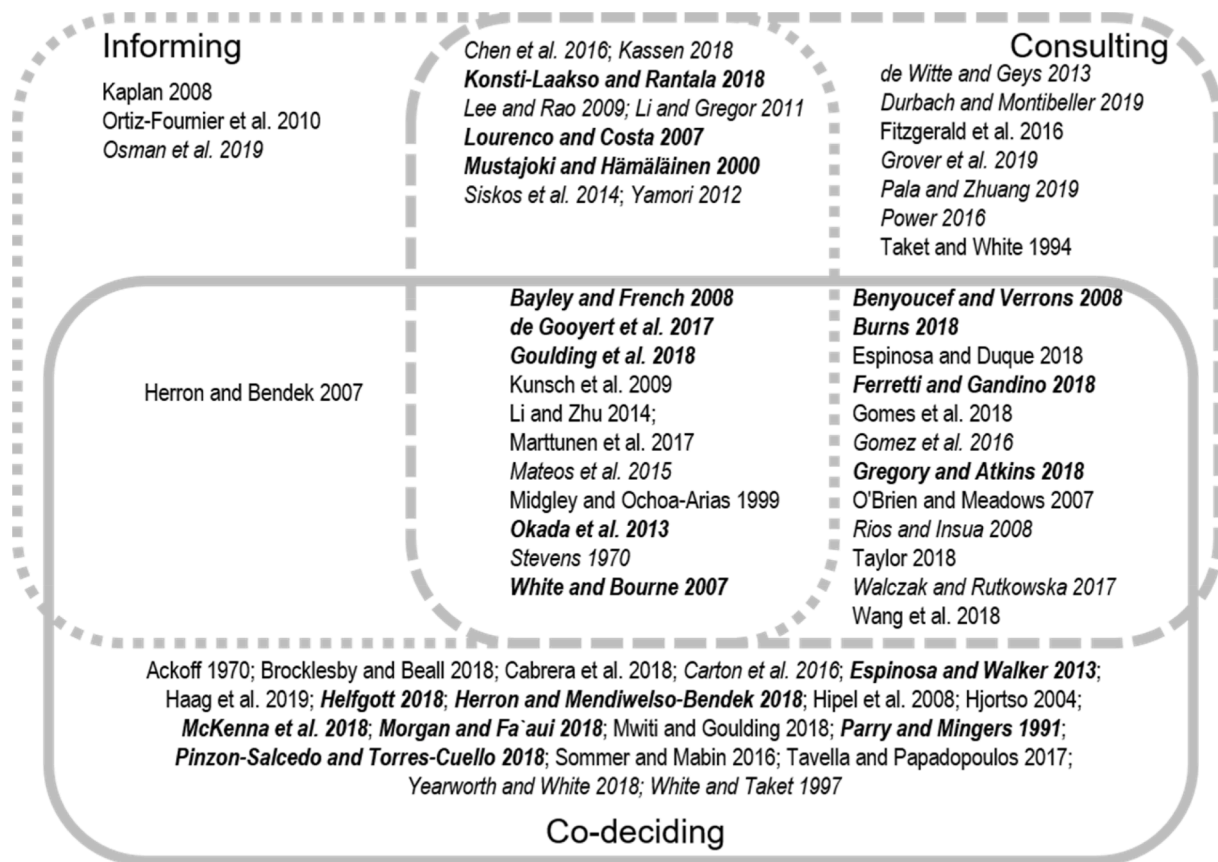
Fig. 3. Aim of participation: informing, consulting, co-deciding, or combinations of these, and the participatory democracy paradigm: increasing the depth in roman, *increasing the breadth in italics,* **increasing both depth and breadth in bold italics**.

workshops. Most targeted a limited number of participants or a group (e. g., 11 in Hjortso, 2004; 25 in Fitzgerald et al., 2016), but others included up to hundreds of participants split into smaller working groups (White and Bourne 2007), or spread participation over a year (O'Brien and Meadows 2007), or even longer-term interventions (e.g., three years in Espinosa and Walker 2013). The other type used digital tools. These aimed to increase the breadth of participation, sometimes combined with the aim of increasing the depth of participation.

Many papers in our corpus concerned broad participation taking place in physical meetings, at the microscale, for instance at the community level. Participation tools and methods included stakeholder workshops, citizen's juries, and focus groups (Bayley and French 2008). Those that were used with laypeople without a representative mandate combined, for instance, visioning activities and transect walks (Helfgott 2018), or specifically designed card games with onsite guided tours and discussions (Okada et al. 2013; Yamori 2012). The card game design encouraged users to consider possible choices in the case of a natural disaster: facing a dilemma, or ethical trade-offs. Another example for the same target group, citizens in Japan facing natural disasters, used an arts-based methodology (Goulding et al. 2018). These authors involved laypeople in specially designed creative activities, such as dramatic and plastic arts. These context-specific activities were conducted over months, and facilitated experiential learning. Grover et al. (2019) interviewed an extensive number of underprivileged local citizens in rural India. This informed the policy-makers about the local constraints of people in their daily lives, and the participants gained a greater appreciation of the macro-level constraints of policy-makers. Findings from the interviews enabled a prediction matrix to be calculated for a MCDA, and in turn policies to be formulated about distributing food grain to poor rural households in India. Fitzgerald et al. (2016) used a metaphorical-thinking brainstorming technique involving a series of

diverse images in workshops to motivate citizens without a representative mandate to brainstorm about the research and technological innovations that they would like to see publicly funded (at the macroscale). In another example, over a hundred local citizens took part in a community workshop during which a problem-structuring method was used to decide about the future of a local hospital in the UK; these were combined with interactions targeting representatives (White and Bourne 2007). All these interventions to physically involve citizens without a representative mandate were specifically designed for their cultural contexts, many rooted in the qualitative OR tradition.

The papers of our corpus focusing on ICT are described in Section 3.7.

Our review showed the diversity of OR methods and tools used to foster citizen participation. The choice of methods, and thus tools, seemed to depend on the type of OR as well as its purpose. Some tools, such as the civic technology ones, can easily include a large number of citizens. However, instances of classical face-to-face methods, particularly originating from Community OR, showed that larger groups of citizens (e.g., up to 200 to 300) can also be involved in local citizen participation events (e.g., Goulding et al. 2018; Grover et al. 2019).

3.5. At which scale are citizens involved in OR?

The scale of the OR process ranged from micro (local) to macro (society) (French et al. 2005). We found instances for all scales. Thirty-nine references focused on the microscale. Among these, twenty-eight qualified as Community OR (Table 2, SI). The other 12 references for the microscale, not identified as Community OR, focused on local geographical scales, such as villages, districts, cities, and regions (Table 2). Community OR appeared as a specific subset of OR processes for the microscale.

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Nine papers targeted the macroscale, focusing on society generally (Table 2). All used ICT and/or big data, except two (Fitzgerald et al. 2016; Hipel et al. 2008), which dealt with a national population sample through a facilitated workshop. Fitzgerald et al. (2016) reported difficulties when engaging with citizens, which might be due to a perceived distance or disconnection between the citizens, and the decisions they were involved in (European research strategy).

Interestingly, the scale of the OR process was not directly related to the number of citizens involved. We found micro-scale OR processes with relatively large citizen involvement, such as the 200 citizens addressed in Goulding et al. (2018). This participation at the microscale was as large as some macro-scale OR processes, for instance involving 150 in Lee and Rao (2009), or 128 in Li and Gregor (2011). Sometimes, micro-scale OR processes involved more citizens than macro-scale processes (only 25 in Fitzgerald et al., 2016, Table 2). However, the largest citizen samples were only found for the macroscale (Mateos et al. 2015; Osman et al. 2019). Both these samples involved several thousand citizens through ICT and/or big data.

3.6. When did OR consider citizens?

It is noteworthy that the topic of citizen engagement is not new to the OR field. It was raised as early as 1970 (e.g., Ackoff 1970; Stevens 1970). Stevens (1970) presented a "citizen feedback project" that was developed in Puerto Rico. It established a multidirectional flow of information between government, citizens, and science, in contrast to the hierarchical, one-way channel from government to citizens that predominated at that time. He described what would today be called a citizens' forum and participatory computer-assisted community workshops. He was convinced that "decision models are badly needed in the world of political and social decision-making" (p.590), and that if they were constructed in an open-ended way and used in contexts where judgements and qualitative factors could be incorporated, the resulting decisions would be explicit and thus transparent. Ackoff (1970) reported on a program to support the black community from Philadelphia (USA). Members of the black community themselves applied OR approaches to solve their own issues. This truly participative approach was unconventional and again strongly contrasted with the OR tradition at that time. This was certainly a pioneering Community OR experience.

Since then, Community OR has developed. At its core are engagements with individuals and groups from communities, which can be defined in many different ways (Midgley and Ochoa-Arias 1999). A complementary movement for citizen participation appeared when the web became a daily practice for many (Mustajoki and Hämäläinen 2000). We wish to point out here that our non-exhaustive corpus does not allow the carrying out of a more detailed temporal analysis. Our exemplary sample of the literature can only give insights into main developments. In the Discussion (Section 4.1), we reflect further on the question why OR before the 1970s did not have meaningful citizen participation.

3.7. Focus on digital tools for citizen participation in OR

Information and communication technologies (ICT) progress and, more recently, social media, big data, and artificial intelligence, have created new opportunities for OR to engage with citizens. To deepen the analysis of our corpus, we focused on digital instruments and techniques (Bayley and French 2008) that enable citizen participation in OR. First, we review the emergence of words describing digital citizenship. Then, we provide examples of digitalized OR tools for citizen participation in public decision-making. We finish by focusing on social media, big data science, analytics, and open data in OR.

The earliest paper from our corpus arguing that ICT progress enables new forms of citizen participation in OR dates back to 2000 (Mustajoki and Hämäläinen 2000). Mustajoki and Hämäläinen (2000) seized the opportunity created by daily use of the internet in private houses to develop an online tool for MCDA, including weight elicitation from individuals. They announced opportunities for "teledemocracy" (p.218), a term that means remote democracy. More recent papers have replaced this term with "e-democracy" and "e-governance"; e-governance encompasses e-democracy (Siskos et al. 2014).

E-democracy stands for electronic democracy and means a democratic system in which the individuals' concerns expressed through electronic tools are considered by the institution with decision-making power (e.g., Lourenco and Costa 2007; Rios Insua et al. 2010). Mateos et al. (2015) defined it as follows: "e-democracy articulates political and democratic procedures involving citizens in societal decision-making through the use of ICT" (p.634). E-democracy comprises two aspects: e-voting and e-participation (Lourenco and Costa 2007). According to these authors, e-participation can use various channels, including websites, emails, frequently asked questions, chats, forums, and other specifically designed interfaces.

E-governance stands for electronic governance and refers to managing an institution with electronic tools (e.g., Lee and Rao 2009). E-governance consists of the online delivery of governmental services, such as taxation and car registration (Lee and Rao 2009; Li and Gregor 2011). Siskos et al. (2014) defined e-government as "the use of information and communication technologies (ICT) by governments to provide digital services to citizens and businesses over the Internet, at local, national or international level" (p.51).

M-governance stands for mobile-governance, and appeared even more recently due to technological progress offering ubiquitous and fast mobile and wireless technology. Consequently, connected mobile devices gradually replaced personal computers in fixed environments (Chen et al. 2016). In the era of big data, the concept of the digital self or digital individuals has emerged. The digital self both empowers us and creates a need for information and exchanges with others (Carton et al. 2016).

Our literature search revealed that OR has embraced technological developments that serve the purposes of democracy. The development of digital interfaces enabled digital participation of citizens in OR. We found several examples of digital OR tools: platforms for MCDA, for e-participation, and for e-voting (Table 4).

Additionally to progress in ICT, advances in data science also provided new ways to involve citizens in OR processes for public decision-making. Citizens can become either data providers or data users. One publication investigated the role of the affordances of social media for community empowerment and participation (Yearworth and White 2018). Analyzing Twitter and Facebook data following a flood event, they found that social media were a hybrid forum in which some problem-structuring had occurred. A hybrid forum is an open space where discussion occurs at different levels including several domains between a heterogeneous group of involved persons (Callon et al. 2009). The authors, OR practitioners, questioned their role in this context (how much should they intervene?), and suggested further research. Two publications (Durbach and Montibeller 2019; Power 2016) highlighted the potential of artificial intelligence, big data, and predictive and behavioral analytics to serve society. Power (2016) warned about the possible risks of such developments, while recognizing that wise use, supported by aware OR scientists, can make a positive difference in citizens' lives (discussed in Section 4.4). Durbach and Montibeller (2019) presented three ways of using big data: (1) detecting behaviors in a descriptive approach, similar to approaches assessing citizens' satisfaction with civic technology, specifically electronic governmental services, (2) exploiting the behaviors described, and (3) improving the judgement of citizens in public contexts, for instance by developing procedures that would debias the behaviors. According to these authors, the third point, improving the judgement of citizens in public contexts, is underdeveloped. The emerging field of behavioral OR (Franco et al. 2021) may investigate this issue. These last two publications where citizens become data providers – sometimes not being aware of or interested in playing an active role in problem solving – recalls the early

Table 4
Examples of digital tools found in our review.

1. Decision support platform for individual and group decision-making using multi-attribute value theory, e.g., Web-Hipre (Hämäläinen et al. 2010; Mustajoki and Hämäläinen 2000)	Participants, including citizens, can provide relative importance (weights) given to several objectives through different methods, and value functions. Web-Hipre enables visualization of the elicited preferences and resulting performance of options, and sensitivity analysis for single parameters. It enables remote interactions with the system. It has been used among others, in a facilitated group meeting for participatory decision-making on lake regulation policy in Finland involving local citizens. Authors suggest that it could also be used in remote decision analysis interviews.
2. Digitized version of the Mauri model. MauriOmeter (Morgan and Fa`aui 2018)	Together with the community, a Mauri model decision-making framework was developed, to support decisions in line with the values of Māori. It followed the Kaupapa Māori methodology. A digitized version was derived. It empowered the communities.
3. Unified toolkit with comfortable interface for local users deciding on energy systems (McKenna et al. 2018)	The authors suggested that their multi-methodological approach to support community decisions on energy systems would benefit from a unified toolkit. They proposed using automated natural language outputs, a comfortable interface, and a potentially open source toolkit. After learning how to use this (to-be) tool, individual communities could develop their energy concept autonomously.
4. Digital systems supporting e-participation or e-negotiation, e.g., electronic forum for online problem-structuring method procedure to write documents collaboratively (Benyoucef and Verrons 2008; Lourenco and Costa 2007)	These digital tools enable participatory writing, for instance for creating policy drafts at the municipal level. Many participants, including citizens, can contribute. The two references and those that were cited in the two papers did not include real-world application. These papers proposed various mathematical procedures to aggregate the votes of individual citizens about the distribution of a shared resource. It concerned a fixed budget, and the procedures allowed using incomplete information collected from citizens' votes, with the aim of increasing citizen satisfaction. The methods were empirically tested in some cases (e.g., Walczak and Rutkowska 2017).
5. E-voting, also termed web polling or procedures, for participatory budget allocations (Mateos et al. 2015; Rios and Insua 2008; Walczak and Rutkowska 2017)	

years of OR, when OR was not yet constituted as a discipline, but already existed as a method of analysis (Pollock and Maltz 1994). OR evolved from social statistics (Pollock and Maltz 1994), and big data seems to be reviving this.

Finally, open data should improve digital communication and thus transparency between citizens and public administrations (Gregory and Atkins 2018; Kassen 2018). These authors defined open data as reusing publicly available governmental datasets and files to distribute, reformat, and use them in local to national governance. Open-data projects contribute to active citizen participation in digital public decision-making, such as in e-governance. The political will of independent developers is extremely important to civic engagement and collaborative projects in the e-governance sphere (Kassen 2018). Big data and data science provide emerging means for citizens to contribute to OR processes for public decision-making. Future work will show the extent to which this opportunity is followed.

4. Synthesis and open questions

Three research questions guided our review: What is the status of citizens in OR? And why and how does citizen participation occur in OR processes? We start by discussing the status of OR for, with, and by citizens (RQ1), and continue with the drivers (RQ2), and enablers (RQ3). Finally, we list four sensitive issues when dealing with citizen participation in OR that we encountered in our review and that deserve particular attention. Researchers interested in involving citizens in OR processes should be aware of these points.

4.1. What is the status of citizens in OR research? (RQ1)

The 62 publications in our corpus spanned from 1970 to 2019. This span indicates that citizen participation has been a theme in OR for the past 50 years (or longer). OR as a discipline appeared shortly before the Second World War, and was also recognized as a profession around that time (Pollock and Maltz 1994). Three guidelines from that time most likely influenced OR for decades, if not until now: the constitution of multidisciplinary groups, long and direct engagement of the OR analyst with clients, and access to the highest-ranked decision-makers (Pollock and Maltz 1994). Consequently, OR solved socially important problems, but did not necessarily consider it as being important to involve the citizens. The social upheaval occurring in the 1960s triggered OR to address needs from the citizens more directly, although it was not clear yet how to engage them (Pollock and Maltz 1994). This crisis in OR led to the emergence of the soft OR and problem structuring methods (Rosenhead 1989). Different terms are used to characterize these individuals that we call citizens (e.g., under-represented people, members of a community, the general public, etc.). Based on our review, we defined this OR-citizen-relation as having three aspects: OR carried out *for* citizens, OR *with* citizens, and OR *by* citizens. This framing is also the core of the Kaupapa Māori methodology promoting research for, by, and with Mauri people (Morgan and Fa`aui 2018, Table 4). Similar aspects concerning stakeholder participation have been raised in the environmental modelling community (e.g., Hämäläinen 2015; Voinov et al. 2016).

OR for citizens. OR is for citizens because it can support decision-making and policy-making to improve citizens' lives (Kaplan 2008). This conclusion is not surprising because, in essence, OR aims to improve our society, to identify "a good or better way of proceeding," and supports change in general (EURO the Association of European Operational Research Societies 2020). Examples of applications include optimizing public transport scheduling (Daraio et al. 2016), optimizing delivery routes to the elderly (Kaplan 2008), various policy modelling (Johnson 2012), e.g., improving vaccination strategy (Duijzer et al. 2018), or modelling the effect of needle exchange programs to prevent further spread of HIV (Kaplan 2008). Our review confirmed that OR is both for citizens and the wider society. We found examples from both quantitative and qualitative OR traditions, e.g., for improving food safety (Bayley and French 2008; Grover et al. 2019) or access to healthy food (Wang et al. 2018), resilience to natural disasters (Goulding et al. 2018; Morgan and Fa`aui 2018; Okada et al. 2013; Yearworth and White 2018), management of the commons (e.g., water in Cabrera et al. 2018; Gomes et al. 2018; Hämäläinen et al. 2010), management of public infrastructure (e.g., hospitals in White and Bourne 2007), or public services such as libraries (de Witte and Geys 2013). The literature from Community OR also comprises humanist themes, such as peace building (Burns 2018), addressing poverty and gender issues (Mwiti and Goulding 2018), or preventing sexual trafficking of children (Taylor 2018). Additionally, some empirical OR papers have aimed to improve online governmental services to citizens for administrative procedures (e.g., Lee and Rao 2009), and participatory budget allocations (e.g., Rios and Insua 2008). OR serves citizens: it is used for providing citizens with optimized services and improved living conditions.

OR with citizens. OR is carried out with citizens when they are

directly involved in OR processes. "Working with people and not on behalf of them" (p.1000) is essential to Community OR (Brocklesby and Beall 2018). OR processes can focus either on participation of a large number of citizens in a participatory paradigm, or on the deep understanding of the problem at stake by a few representative stakeholders in a deliberative paradigm (de Gooyert et al. 2017; Gregory et al. 2016; Papadopoulos and Warin 2007). Involving citizens as representatives of specific interest groups is part of the essence of many OR processes (EURO the Association of European Operational Research Societies 2020). Traditionally, Community OR has focused on the participation of citizens who do not have representative mandates (Johnson 2012; Midgley et al. 2018; Midgley and Ochoa-Arias 1999), or are under-represented because they have no voice (Ackoff 1970; Taket and White 1994; White and Bourne 2007). Community OR has also addressed a grass-root organization level (Espinosa and Walker 2013; Tavella and Papadopoulos 2017). In our review, most papers from Community OR used mixed methodologies, including for instance Soft OR tools, MCDA, or other activities such as arts and games (Okada et al. 2013; Yamori 2012) to engage citizens in deliberative processes (Papadopoulos and Warin 2007). Some OR processes are able to expand the range and number of citizens to include hundreds of people (e.g., Cabrera et al. 2018; Goulding et al. 2018). Finally, ICT progress has enabled digitalization of OR tools and methods, which offers an additional means to increase citizen participation. For instance, e-voting for participatory budget allocations allowed the engagement of many citizens in local decisions (e.g., Mateos et al. 2015). Whether in person or digitally, OR processes can directly engage with citizens.

OR by citizens. Several publications have highlighted the role of OR scientists in citizen participation processes, or have questioned it (Kaplan 2008; Mwiti and Goulding 2018; Parry and Mingers 1991; Yearworth and White 2018). The OR scientists, citizens themselves, are always among the involved stakeholders. As scientists, they traditionally endorse a facilitator and/or observer role (Ackoff 1970; Burns 2018; Espinosa and Walker 2013; Konsti-Laakso and Rantala 2018; Taket and White 1994). In some cases, when the rationale for citizen participation was moral, some OR scientists considered themselves as "citizen scientists" (Gregory and Atkins 2018, p.1117). Gregory and Atkins (2018), Li and Zhu (2014), and Midgley and Ochoa-Arias (1999) emphasized that OR scientists can be driven by their sense of contributing to society as engaged citizens. For instance, "[t]he future of OR … will be determined by whether OR workers are willing and capable to act as institutional entrepreneurs promoting scientific and democratic decision-making" (Li and Zhu 2014, p.427), and "[t]here are therefore substantial political choices open to those involved in Community OR" (Midgley and Ochoa-Arias 1999, p.259). Rosenhead's 'Custom and Practice' address to the UK OR Society as he became its president is another example of very engaged text (Rosenhead 1986). Papers on ethics in OR suggest that OR should simply be put at the service of society as a whole, including for the citizens' good (for papers about OR and ethics, see e.g., the review by Ormerod and Ulrich (2013), and special issues: Brans et al. (2010); Le Menestrel et al. (2009)). OR scientists are partly responsible for fair and ethical OR processes.

4.2. A moral driver of citizen participation in OR (RQ2)

Our review indicated that citizen participation in OR is often driven by (1) the search for a democratic ideal, and (2) the personal commitment of some scientists. First, the search for a democratic ideal has guided and may still guide the (further) development of OR. Originally, OR as a scientific discipline emerged to help society (Ackoff 1970; Johnson 2012; Kaplan 2008), but it mostly developed within corporate and public organizational management settings (Gregory and Atkins 2018; Hjortso 2004; Rosenhead 1986). This led to an "OR crisis (…) in the 1970s and 1980s" (Pinzon-Salcedo and Torres-Cuello 2018, p.946). Ackoff (1970) initiated in the USA the proposition to take OR into the field of community development. In the UK, this movement was led by

Rosenhead (1986). One argument for being more inclusive was that values that may be held by only one or two individuals are particularly important, because they might represent the voices of a minority. Moreover, they might be held with great intensity, making trade-offs especially demanding but crucial to elicit (White and Bourne 2007). The search for a democratic ideal can open new opportunities for OR research, for instance by engaging with entities that so far have not benefitted much from OR support. Community OR has pioneered in this domain (Ackoff 1970; Johnson 2012; Midgley et al. 2018).

Generally, initiatives for citizen participation have emerged from engaged citizens in search of this democratic ideal, some of them being OR scientists. OR scientists involved in participatory OR processes have been well accepted as facilitators and/or knowledge brokers, i.e., those who bridge between different perspectives and distribute knowledge from one to the other. OR scientists have been perceived as particularly competent in primary data collection (Konsti-Laakso and Rantala 2018). Gregory and Atkins (2018) called for OR scientists to take responsibility for their citizenship and proactively contribute to the development of participatory OR processes to empower citizens. Likewise, Li and Zhu (2014) stressed that "OR workers have a decision to make" to use their competencies and capabilities for morally justified purposes. The use of OR processes engaging citizens in public decision-making is likely only possible if OR scientists are motivated to do so and actively engage more in such projects. In sum, the motivation of the project owner, the sponsor of the process, and of the supporting OR scientists will determine the degree to which an OR process will be participatory.

4.3. Technology: an enabler of citizen participation in OR (RQ3)

The corpus reviewed here revealed one recent enabler for citizen participation in OR processes for public decision-making: ICT progress. Nonetheless, although being an enabler, we also observed many participatory approaches with meaningful engagements of numerous individuals in processes not supported by ICT. Community OR does not need ICT to engage with hundreds of persons (e.g., Espinosa and Duque 2018; Yamori 2012), but has also started to consider ICT (McKenna et al. 2018; Morgan and Fa`aui 2018; Yearworth and White 2018). In Section 3.7, we reviewed the terminology associated with digital decision-making for public issues, and presented examples of digital tools that support OR processes for enhancing citizen participation. Thereafter, we identified emerging trends related to social media, big data, and open data, which suggest that innovative research will emerge at this interface. New technologies should not only support traditional OR procedures with new tools, but also contribute to transforming our democratic practices (Lavin and Rios Insua 2010).

Technological progress has enabled new tools to appear. For instance, deliberative processes enhancing representative stakeholders' deep understanding of problems were supported by e-negotiation platforms (Benyoucef and Verrons 2008; Lourenco and Costa 2007). The use of ICT has increased the breadth of citizen participation in OR processes (Fig. 4), specifically by enabling many citizens without a political or representative mandate to participate (e.g., Bayley and French 2008; Carton et al. 2016; Durbach and Montibeller 2019; Mateos et al. 2015). However, apart from participatory budget tools, we found few examples (Table 4), and further empirical cases using digital tools would be needed for deeper insight into their advantages and disadvantages. Digital tools can be used remotely, which is an advantage because it allows many citizens to participate. Despite this, support by facilitators might be required to (1) guide the participants through the tool and possibly motivate them to contribute, and (2) ensure that the tool is used as intended, which includes checking that the process is understood by participants, and that the use of intuitions or heuristics is made explicit so that their use would be a conscious choice (Hämäläinen et al. 2010).

Recently, interfaces for population surveys have been developed specifically to support OR processes for public decision-making (e.g., Aubert et al. 2020; Gregory et al. 2016; Lienert et al. 2016). We also
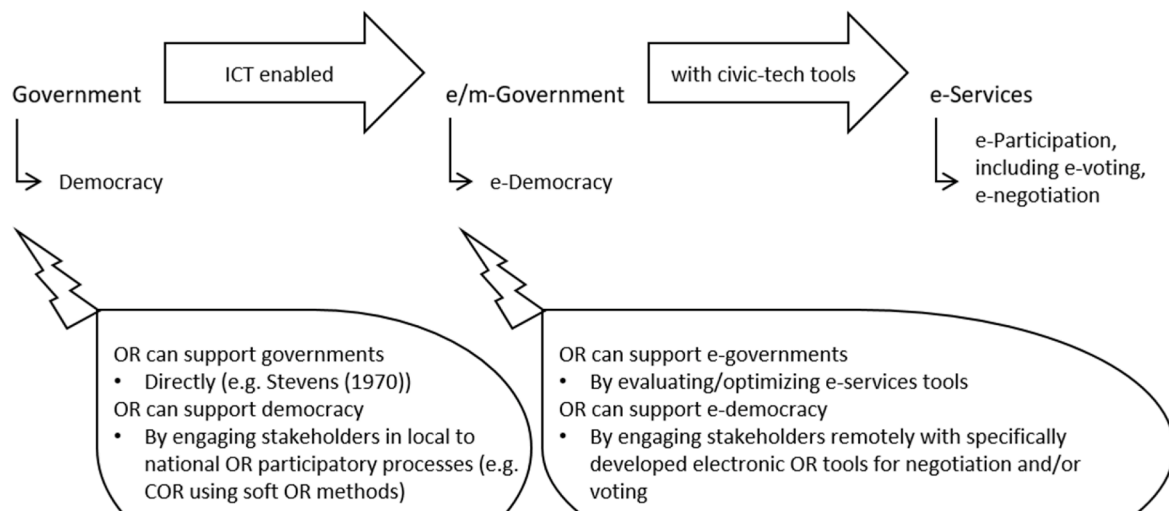
Fig. 4. Either physical means or digital civic technologies are used for enabling participation of citizens in OR processes. COR: Community OR.

gamified one such online survey (Aubert et al. 2022). The most common argument for online public decision-making is that it moves towards the participatory paradigm and allows for broad participation. Digital tools for OR processes should help meeting the requirements for inclusive and diverse participation. However, several authors have raised the issue of the digital divide (Córdoba and Midgley 2008; Lourenco and Costa 2007; Osman et al. 2019). Some parts of the population may not have access to high-quality bandwidth, mobile coverage, and high-speed internet (Osman et al. 2019). Additionally, not all citizens are computer literate, which may marginalize some age groups. With digital tools too, the context of the public OR process will determine the most appropriate participation strategy.

4.4. Sensitive issues when dealing with citizen participation in OR

4.4.1. Who participates, with which role?

In essence, all participants in OR processes are citizens, albeit with different roles (de Gooyert et al. 2017; Konsti-Laakso and Rantala 2018). The project owner or sponsor initiates the process, often together with the decision-maker, which is the most powerful role. Other roles include the facilitators, who are often OR scientists and analysts. Experts can intervene as external consultants, scientists may provide background knowledge, and sometimes a broker is included (Konsti-Laakso and Rantala 2018). It is important to reflect on how much these roles can influence the decision at stake, while facilitators and OR analysts will usually try to be mere enablers. As human beings, we are characterized by limited understanding and value-laden positions; even for instance when deciding how to facilitate a participatory decision-making process (e.g., Helfgott 2018). In most OR processes, the other people involved are representatives of the various interest groups who are neither decision-makers nor facilitators.

An important open question is how inclusive OR processes should be? Being inclusive implies broad participation of citizens as affected laypeople. Our review indicates that laypeople mostly participated in OR processes for public decision-making at the microscale, i.e., locally (e.g., Gomez et al. 2016; Konsti-Laakso and Rantala 2018; Walczak and Rutkowska 2017). The single example from the macroscale documented a nationwide workshop and reported difficulties for citizens in engaging with the broad theme of setting research priorities for society-relevant innovation (Fitzgerald et al. 2016). This raises the following question: Is broad participation realistic at the macroscale?

Participation in OR processes also opens central questions about legitimacy, which is a point often mentioned in the Community OR literature (Helfgott 2018; Morgan and Fa`aui 2018; Taket and White

1994). Stakeholder analysis and social network analysis (e.g., Lienert et al. 2013) help to rigorously identify all interest groups: those with power and influence, who may be central actors, and those affected by decisions. Stakeholder analysis supports rigorous stakeholder identification (Gregory et al. 2020). However, a sound identification process does not necessarily mean that all will participate. For instance, Hämäläinen et al. (2010) faced difficulties in attracting local inhabitants. This raises another question: how can all relevant stakeholders be included in their diversity? To learn from participatory processes, each of which is unique (Konsti-Laakso and Rantala 2018; Rios Insua et al. 2010), some authors advocate using reporting protocols that systematically describe the contexts of the participatory processes (Cockerill et al. 2019; Reed et al. 2018).

Another critical aspect is power distribution: How much power should be transferred to the citizens? Are they co-deciding, or solely to be consulted or informed (de Gooyert et al. 2017; Hjortso 2004; Konsti-Laakso and Rantala 2018)? Arnstein (1969) was the first to discuss the varying degrees to which influence and power is transferred to citizens in her ladder of participation. The ladder structure suggested that fully empowering citizens is the ultimate goal. However, this normative goal has since been debated (e.g., Collins and Ison 2006; Reed 2008). Community OR often aims at empowering communities (Burns 2018; Espinosa and Walker 2013; Gregory and Atkins 2018; Helfgott 2018; Herron and Mendiwelso-Bendek 2018; Morgan and Fa`aui 2018; Mwiti and Goulding 2018; Pinzon-Salcedo and Torres-Cuello 2018; Taket and White 1994; White and Taket 1997; Yearworth and White 2018). In OR processes with clear sponsors and decision-makers, which qualify as top-down processes, the following question needs to be considered: how much influence can or should citizens have in identifying, formulating, and solving decision problems that are important to them? Is it possible to imagine that citizens are given all the power? To answer these questions, theories of empowerment from the psychology and organization science literatures that distinguish between processes and outcomes (Li and Gregor 2011), and the seminal work of Ostrom (2009), on self-organization and collective action, might provide starting points.

Finally, a fundamental aspect of participatory OR processes is trust (Burns 2018; de Witte and Geys 2013; Herron and Mendiwelso-Bendek 2018; Li and Gregor 2011; Lourenco and Costa 2007; Mwiti and Goulding 2018; Pala and Zhuang 2019; Taket and White 1994; Yearworth and White 2018). How trust is built and maintained is far beyond the scope of this review. However, it is important to at least mention trust, as it can modulate the motivation of citizens to participate in OR processes for public decision-making, and thus their commitment to the outcomes of the process. Recognizing and addressing issues of diversity,

equity and inclusion, and social and racial justice is essential to establishing and improving levels of trust among citizen participants in OR problem solving processes (e.g., Johnson and Chichirau 2020). Reading literature from complementary fields such as participatory modelling and risk analysis (Cockerill et al. 2019; Poortinga and Pidgeon 2003) is surely a helpful starting point.

4.4.2. How can the contributions of many individuals be aggregated?

The participation of several hundred citizens in either physical or digital processes entails choosing a method to aggregate their inputs. In the qualitative OR tradition, the mere consideration of a diverse and inclusive participation process ensures that the respective voices and values will be taken into account. The aim is not necessarily consensus, but recognizing the value of differences (Taket and White 1994). In the quantitative OR tradition, mathematical aggregation seems to be the most practical solution. However, a wide choice of aggregation methods exists (for an overview, see Efremov and Insua 2010). Often, authors refer to social choice theory and Arrow's impossibility theorem (e.g., Munda 2008; Mustajoki and Hämäläinen 2000). One aggregation option is to weight the individuals' answers (Rios and Insua 2008), and this can be done in many ways. For instance, Mateos et al. (2015) assigned weights by the number of citizens that participated in the decision-making process and by how much various political groups were represented. Their aim was to represent the citizens that were not directly included in the intervention in proportion to their political representatives. Others with large samples of citizens took the median, as in many democratic votes (Durbach and Montibeller 2019). A separate specific review might be carried out concerning aggregation principles when dealing with broad citizen participation in OR processes for public decision-making (such as Efremov and Insua 2010).

4.4.3. How can contributing citizens and their data be protected?

Several conceptual papers in our corpus reviewed the issue of "privacy, surveillance, and government abuse of data" (Power 2016, p.578), and to some extent, cybersecurity (Pala and Zhuang 2019). Data protection and voluntary consent to participation have always been concerns for many fields of research involving human subjects, such as psychology. They have also been a concern for OR, albeit in practice less strictly. For instance, all participants are usually anonymized in publications. However, we enter another dimension if OR processes move online and become digital (McKenna et al. 2018). Power (2016) raised the issue that there is a risk that governments may misuse technologies to control their citizens, and warned that "decision support researchers must understand the issues and resist attempts to use information technologies to support current or future totalitarian governments" (p.578). In their review of over 82 papers on cybersecurity, Pala and Zhuang (2019) mentioned that trust in the organization or the decision sponsor is necessary for citizens to share information. Moreover, interfaces should ensure that citizens willingly share information, for instance by explicitly asking them to approve its disclosure. Researchers should also adopt state-of-the-art measures for protecting data. For online OR practice, giving a token to participants would protect their anonymity. We raise this topic as a relevant one, but in-depth analysis of it is beyond the scope of this paper.

4.4.4. How can citizen participation in OR processes be evaluated?

Our review highlighted many approaches for citizen participation in OR processes. Choosing the most appropriate method or tool will depend on the context (who, where, when, and why) (Reed et al. 2018). We learnt from Community OR that meaningful engagement often requires mixed methods (e.g., Burns 2018; Cabrera et al. 2018; Espinosa and Duque 2018), and a mid- to long-term engagement (e.g., Ackoff 1970; Herron and Mendiwelso-Bendek 2018; Pinzon-Salcedo and Torres-Cuello 2018). However, evaluation of citizen participation is challenging (de Witte and Geys 2013; Espinosa and Walker 2013; Helfgott 2018), and also context specific. We found some interesting

attempts in our review (Bayley and French 2008; Hjortso 2004). We would like to highlight three other review papers that are concerned with the systematization and evaluation of OR processes (Franco et al. 2021; Midgley et al. 2013; White 2006). The classic division of ethics could be helpful here: proper conduct, rights, duties, and consequences are all relevant, with a strong case to argue that the evaluation of an intervention should be based on the stakeholders' perception of the outcomes (Brans et al. 2010; Le Menestrel et al. 2009; Ormerod and Ulrich 2013).

5. Conclusion

Citizen participation is topical in science and society. We reviewed an exemplary sample of the OR literature concerned with citizens and found that OR work embracing citizen participation is very diverse. Community OR has been leading the way for meaningful engagement of individuals since the 1970s. In general, OR's purpose is to find good or better ways of solving strategic problems and managing the implementation of the proposed solutions. This should improve citizens' living conditions when applied to public services. Additionally, some OR processes are conducted with citizens, or at least with some representatives taking part in the process. Moreover, if we consider that OR scientists are also citizens we can say that all OR processes are actually conducted by citizens! In principle, these OR scientists (we ourselves) can support participatory processes for a democratic ideal. Whether this is often done in practice is another matter, but many of those who actually do support participatory processes are driven by a moral ideal.

Our review revealed a variety of participatory methods and tools that allow citizens to be engaged in OR processes. Methodological pluralism is current in qualitative OR work, including that undertaken with citizens (early work in this field was undertaken by, e.g., Gregory and Jackson (1992)). Visualization tools (e.g., rich pictures), art-based approaches, or interactive activities such as walks or games are tools that can be inclusive for in-person processes. We also observed an increase in digitalization of OR processes, which can broaden public participation, for instance with e-negotiation or e-voting platforms, or specifically designed surveys. The OR researcher interested in engaging with citizens should reflect on the context and choose the most appropriate degree and means of citizen participation.

We have identified a number of worthwhile avenues for future OR research. These include (1) joining the Community OR endeavor to engage with citizens and stakeholders who have so far rarely been supported by OR processes. We could ensure citizen empowerment, meaning that we give decision power to citizens, instead of applying processes that only inform or consult. We could also support bottom-up processes, meaning that they are initiated by the citizens themselves, thus making the citizens the decision-owners. (2) OR research should investigate digital OR methods and tools in empirical cases to identify their benefits and drawbacks for the OR processes and their outcomes. (3) We could investigate whether the participatory democracy paradigm, which aims at involving as many citizens as possible, is suitable for OR processes at the macro or societal scale. (4) We should also investigate how to build and maintain trust in OR processes, and; (5) ensure that the practice of OR protects participants' data. (6) To advance learning in the field, it is important to systematically report, evaluate, and reflect on participatory OR processes. Finally, (7) OR should continue research on ensuring that the aggregation of individual inputs is as fair as possible (in the case of the quantitative OR tradition). Meeting the challenges raised by these points will significantly contribute to OR fulfilling its mandate of better decision-making in close cooperation with all affected stakeholders. We are also convinced that addressing these questions provides interesting and relevant research opportunities for OR scientists.

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Supplementary materials

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