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Review

Systematic Literature Review on Robust Optimization in Solving Sustainable Development Goals (SDGs) Problems during the COVID-19 Pandemic

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Abstract: Handling uncertainty is important in decision making, especially for SDGs problems. Robust Optimization (RO) is an applied optimization method that can be employed to handle optimization under uncertain data. With SDGs problems, many uncertain data have been considered in decision making. With RO, the data uncertainties are assumed to lay within a compact, convex continuous set. There are three special sets that can be used to represent the data, i.e., box, ellipsoidal, or polyhedral uncertainty sets. These special sets lead the SDGs problems to a computationally tractable optimization model, such that the global optimal solution is attained. However, literature reviews on the application of RO in SDGs decision-making is sparse, especially during the COVID-19 pandemic period. This paper examines the following topics: (1) the purposes of studies of RO and SDGs during the COVID-19 pandemic, (2) the state-of-the-art in RO-SDGs to determine the research objectives, and (3) the SDGs type of problems that have been modeled using RO. A systematic literature review is conducted in this paper, wherein discussion is based on a PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) flowchart. To this end, the database reference searching conducted on the Scopus, Science Direct, and SAGE databases, is completed using the help RStudio software. The analysis was carried out on two datasets, assisted by the output visualization using RStudio software with the "bibliometrix" package, and using the 'biblioshiny()' command to create a link to the "shiny web interface". In this paper, the research gap on application of RO to SDGs problems is analyzed in order to identify the research objectives, methods, and specific RO-SDGs problems. As a result, the application of RO to SDGs problems is rare; this finding provides a motivation to conduct a further study of RO and SDGs during the COVID-19 pandemic. An expansion is presented using the key phrase "Operations Research and Optimization Modeling", or "OROM". SDGs in Indonesia may be referenced as an example of the capacity building available through RO/OROM.

Keywords: systematic literature review; robust optimization; SDGs; COVID-19

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1. Introduction

The 2030 agenda for sustainable development was adopted by more than 180 United Nations (UN) members in 2015. The agenda consists of 17 Sustainable Development Goals (SDGs) and 169 targets, which fall into 3 main sectors: social, economic, and environmental factors [1]. To support the achievement of the SDGs, the interrelationships between these goals have been studied in various publications, including [2,3]. Further research into how to measure the progress towards SDGs is studied in [4,5].

Even though this agenda has been in place for seven years, the road to attaining all the SDGs remains long [6]. One of the major impediments to accomplishing these goals is

the global crisis caused by the COVID-19 outbreak [7]. COVID-19's impact on the global economy and the social well-being of millions of people, will take years to repair. COVID-19's impact on the global economy and the social well-being of millions of people will take years to repair. Even before COVID-19, The Lancet Public Health estimated that 6% of the global population will remain impoverished by 2030. Furthermore, the percentage of country-indicator scores that are reached is anticipated to be just 53.8% in 2030, which is insufficient to accomplish the complete achievement goals [8].

Various mathematical models have been proposed by past studies, to address issues related to sustainability. These include Linear Programming (LP) [9], Multi-objective Mixed-Integer Linear Programming (MILP) [10], Multi-objective Optimization via Fuzzy Goal Programming [11], and Mixed-Integer Non-Linear Programming (MINLP) [12]. In addition, [13] and [14] investigated the application of game theory in supply chain and water reuse problems. In summary, many studies have addressed the issue of SDGs through Operations Research and Optimization Modeling (OROM).

In this paper, a discussion on how Robust Optimization can help in decision making for SDGs problems during the COVID-19 pandemic is presented. A systematic literature review is conducted in this paper, where discussion is based on a PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) flowchart. To this end, the database reference searching on the Scopus, Science Direct, and SAGE databases, is conducted using the help RStudio software. The analysis was carried out on two datasets, assisted by the output visualization using RStudio software with the "bibliometrix" package, and using the 'biblioshiny()' command to create a link to the "shiny web interface". The chosen keywords are employed using the command: ("Robust Optimization") AND ("Sustainability Development" OR "Sustainability Development Goals" OR "SDGs" OR "SDG").

Comparison with other review papers on the same topic, shows that the keyword combination can help to show the importance of using Robust Optimization methods to plan and solve SDGs problems during the COVID-19 pandemic. This paper examines the following topics as research questions (RQ):

(1) What are the studies purposes of RO and SDGs during the COVID-19 pandemic?;
(2) How the state-of-the-art in RO-SDGs is determined to formulate novel and new research objectives?;
(3) Which SDGs types of problems have been modeled using RO?

In this paper, a study on SLR for SDGs in Indonesia was also performed. This paper is organized in such a manner that Section 2 provides a related literature review, Section 3 presents the research method used to collect the articles for analysis, Section 4 provides discussion of the results, and conclusions and a further research agenda are presented in Section 5.

2. Theoretical Background

2.1. Brief Introduction on Robust Optimization

In this subsection, an overview for robust optimization (RO) is discussed, i.e., the methodology aimed at optimization under uncertainty. Optimization under uncertainty refers to the branch of optimization where there are uncertainties involved in the data. The importance of this class of problem is that in many models the uncertainty is ignored, and a representative nominal value of the data is used. However, the decision variables cannot be perfectly forecast, but instead should be considered random or uncertain. Citing from Ben-Tal [15], the main challenge in using this RO methodology, is how and when we can reformulate the robust counterpart of uncertain problems as a computationally tractable optimization problem, or at least approximate the RC by a tractable problem. Due to its definition, the robust counterpart highly depends on how the uncertainty set U is chosen. As a consequence, this challenge is met only if this set is chosen in a suitable way.

As mentioned in Ben-Tal and Nemirovskii [15], the classical approach in operations research/management science to deal with uncertainty, is stochastic programming (SP).

However, even the random variables are degenerate (i.e., deterministic), and the corresponding SP model does not necessarily recover the original optimization problem, but only a relaxation of these constraints. In other words, SP treats mainly soft constraints. The general formulation of uncertain optimization problems are presented as follows:

$$\min_{x}\{f_0(x,\xi) : f_i(x,\xi) \leq 0, i = 1,\ldots,m\} \quad (1)$$

where the objective function and the constraint functions are dependent on the vectors x and ξ, where x is the vector of decision variables, and ξ stands for the data specifying a particular problem instance. Uncertainty means that the data vector ξ is not precisely known at the time when the solution has to be determined.

Recent advances in development of RO can be found in Gabrel et al. [16]. A discussion of a practical guide to RO is presented by Gorissen et al. [17]. Further development in the methods of RO, such as distributional RO, are discussed by Rahimian and Mehrotra [18], and Lin and Gao [19].

2.2. Related Literature Review

Optimization models can help in decision making for SDGs, for instance in deciding the optimal solution in respect to several SDGs problems, including optimal supply chains allocation, optimal land-use allocation, optimal clean water and sanitary solution, and how to manage the optimal supply-demand to achieve zero hunger. These optimization models were obtained from various relevant sources. On the other hand, for SDGs decision making, we concluded that the use of optimization models needs to be developed. Thus, this situation becomes a motivation to implement Robust Optimization for SDGs decision making. An example of an optimization model is that introduced by [20], which discussed how the land use optimization model, based on the R-package lpSolveAPI for linear optimization, can distribute agricultural land use while minimizing global terrestrial carbon pool losses (L_c) and the global risk of biodiversity loss (R_b), as well as fulfilling scenario-driven food supply constraints. The objective function used is minimizing global terrestrial carbon pool losses and global risk of biodiversity loss that supports the sustainability of SDGs goals or indicators, namely, "climate action" [20].

In addition, an article by [21] introduced an economic optimization model that supports the goals of the SDGs, namely "clean water and sanitation" and "economic growth". Under current and projected climate scenarios, the economic optimization model maximizes the economic benefits of hydropower generation, crop irrigation, and flood damage mitigation for the entire basin. As previously stated, the simulated WEAP model outputs consider surface water, energy production, and reservoir storage capacity, as limits..

The final optimization model example has been included in [22], which reviews the optimization model at the conclusion of the study, and offers some crucial recommendations that would help academics and policymakers create a reliable and effective solid waste collection (SWC) system to achieve SDGs. The most popular optimization, route optimization, is carried out to enhance SWC system collection and transportation. The route with the quickest cost-effective travel time is considered the ideal route in most research. The objective function is formulated based on travel path minimization. Time optimization, cost optimization, allocation/reallocation of bins, waste bin optimization, transfer/collection station, and the environmental impact optimization model, can be further seen in [22].

3. Materials and Methods

3.1. Materials

According to [23], a systematic literature review (SLR) examines a formulated question that uses explicit and systematic methods. These two types of methods are used to select, identify, and critically appraise relevant research, and to analyze and collect data from the studies included in the review. To support the SLR process, we use the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) method. The PRISMA method

requires material from database mining articles sourced from various digital libraries. The database mining results are stored in a ".bib" file format, which contains a collection of selected articles.

The SLR article we are discussing is about how Robust Optimization can help in decision making for sustainable development problems during the COVID-19 pandemic. We use three digital libraries, namely Scopus, Science Direct, and SAGE. In reference to [24], the selected keyword in this paper was performed through RQ analysis, and also by referencing the related paper. For the three digital libraires, article mining limitations are applied which aim to filter articles according to need, namely: (1) articles are open access, which aims to avoid the limitation of filtering articles based on keywords; (2) articles from the period between 1992 and 2021, by considering the COVID-19 pandemic period; (3) articles are in English as an international language; (4) search keywords have been seen in the article's title, keyword, and abstract, since the title, keywords, and abstract are the first to be read by readers; (5) the article database is in research articles and conference papers; and (6) the source type of the database article is journals and proceedings that have been published. In this paper, a manual article-exclusion stage is completed wherein two authors read the abstract and the article content, and indicate whether an article is relevant or not to be considered. Another author participates if a difference of opinion arises. By adding an additional opinion, the final decision is made. The next step of this process is to apply the PRISMA method, which is explained in Section 3.2.

3.2. Methods

In this review, we use PRISMA guidelines for the SLR, as discussed in Moher et al. [23]. PRISMA is chosen as it provides clear guidance for conducting an SLR [25]. PRISMA also improves methodological and reporting quality [26]. Figure 1 presents the steps taken in the selection of articles for review.

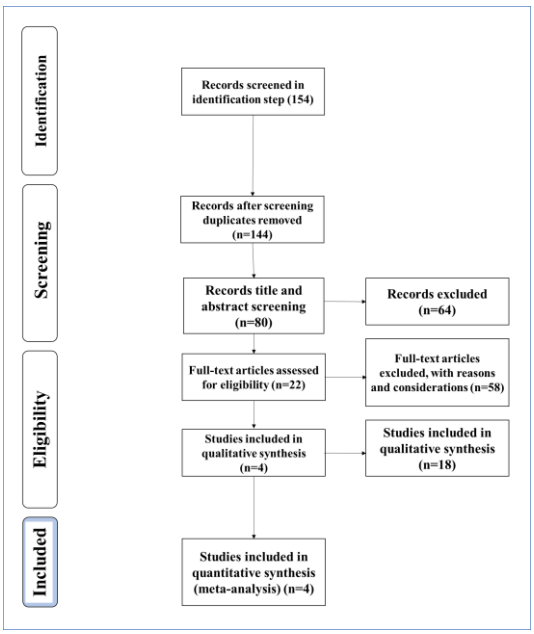


Figure 1. PRISMA Diagram.

3.2.1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Protocol

PRISMA is a protocol designed to assist in creating SLR and meta-analyses for assessing treatment efficacy. PRISMA protocol is meant to be used primarily by authors preparing systematic reviews for publication, public information, or other purposes [27]. Furthermore, the PRISMA method provides a standardized and accurate methodology

for describing article selection criteria, search tactics, data analysis procedures, and data extraction.

The first stage is Identification, wherein the purpose is to identify keywords that are relevant to the research topic plan. Keyword classification is needed in order to provide the best specifications for the article results obtained. The grouping of keywords can be based on the most general to the most specific topics, or in any other manner, according to the researcher's needs, and then input into at least one digital library, to obtain the total identified articles. Furthermore, article limitations are also applied at the stage of inputting keywords into the database, as explained in the previous section. In this article, we use six search limitations.

The second stage is the Screening stage. At this stage, the first thing to do is to screen duplicate articles identified in the first stage. Duplication may occur if using more than one database library, so that it will capture articles with the same title and author. Duplication checks can be done manually or using the Mendeley or Jabref software, so that the total number of the latest articles is finally obtained. The next stage of the screening stage is filtering articles by title and abstract (reading selected articles one by one manually), so that discarded articles, which are not appropriate with research topics, will enter the third stage of the PRISMA method.

Selected articles at the screening stage enter the third stage, namely the Eligibility stage, by checking and reading the articles thoroughly and manually, so that discarded articles that do not match are obtained again. Checking is done by examining the research methods, objectives, and outputs. The result of article selection at the eligibility stage are articles that enter the final stage, which contains a collection of articles that are ready to be used as literature review material, bibliometric map mapping, and state-of-the-art preparation.

3.2.2. "Bibliometrix" in RStudio Software

After obtaining the final article database using PRISMA, a special method is needed, with the help of RStudio software, to support the formation of bibliometric maps. RStudio is open-access software publicly released on 28 February 2011 [28]. RStudio is currently quite stable and adequate for regular use [29]. As a result, it is useful for bibliometric analysis. This paper presents bibliometrix, a unique open-source tool created by the authors for doing extensive science mapping analysis. To perform bibliometric analyses, the "library(bibliometrix)" package, which functions as a comprehensive science mapping, offers a recommended workflow. To run the program, R Software directs the user to directly visit the shiny web interface by typing a new command in the R console, namely "biblioshiny()" [30].

4. Results

4.1. SLR to OROM, RO, and SDGs

In this Systematic Literature Review (SLR) article, we discuss how Robust Optimization can help in decision making for sustainable development problems during the COVID-19 pandemic. Our review complements existing reviews on this topic of how Robust Optimization can helps the SDGs problem in general (Table 1). Table 1 (row 7) shows the comparison between our article and the previous review articles (rows 1 to 6). The difference between our paper and these other review papers, is that we focus on content analysis of OROM, decision making, SDGs, the COVID-19 pandemic, and Robust Optimization. The other review papers did not cover all of the themes covered in our SLR, which indicates gaps in the research. Therefore, our paper would be useful as the latest reference for current and future research for related topics.

In this section, the SLR is discussed. As we employ PRISMA, the discussion is as follows. The first step of the PRISMA method is the Identification stage, which involves keyword determination and data mining based on keywords in three digital libraries (Scopus, Science Direct, and SAGE), as shown in Table 2. The keywords are divided into

four focus areas: Robust Optimization (RO) with SDGs, RO with SDGs during the COVID-19 pandemic, RO with a developing country, and RO with Indonesia. However, based on the topic of this paper, the main focus of the discussion is on the second keyword, while other keywords may be used as support for further analysis of the research gap on the subject of developing countries, especially Indonesia. The database of articles obtained from three digital libraries is totaled based on the keywords, to see whether the number of articles has decreased significantly after the PRISMA method is applied, especially at the screening and eligibility steps.

Table 1. Related previous SLR articles.

No	Author	Title	Content Analysis				
			OROM	Decision Making	SDGs	COVID-19 Pandemic	Robust Optimization
1	[31]	The 2020 report of The Lancet Countdown on health and climate change: responding to converging crises	-	-	✓	✓	-
2	[32]	Blockchain technology for sustainable supply chain management: A systematic literature review and a classification framework	-	✓	✓	-	-
3	[33]	A Systematic Review of Sustainable Fresh Fruit and Vegetable Supply Chains	✓	✓	-	✓	-
4	[34]	Digitalization in food supply chains: A bibliometric review and key-route main path analysis	-	✓	✓	✓	-
5	[35]	Advancing sustainable development goals through immunization: a literature review	-	✓	✓	✓	-
6	[36]	Integrating resilience and sustainability criteria in supply chain network design. A systematic literature review	-	✓	✓	-	-
7		This paper	✓	✓	✓	✓	✓

Table 2. Database mining of RO and SDGs.

Identification (Step 1)						
Code	Category	Keywords	Scopus	Science Direct	SAGE	Total
1	RO with SDGs in General	"Robust Optimization" AND ("Sustainability Development" OR "Sustainability Development Goals" OR "SDGs" OR "SDG")	0	18	0	18
2	RO with SDGs one-by-one	("Operations Research" OR "Optimization Model") AND ("Sustainability Development" OR "Sustainability Development Goals" OR "SDGs" OR "SDG") AND ("(18 types of SDGs)")	0	0	0	0
A	RO with Developing Country	"Robust Optimization" AND "Developing Countries"	11	3	8	22
B	RO with Indonesia	"Robust Optimization" AND "Indonesia"	3	1	5	9
C	RO with COVID-19	"Robust Optimization" AND ("Sustainability Development" OR "Sustainability Development Goals" OR "SDGs" OR "SDG") AND ("Pandemic COVID-19" OR "COVID" OR "COVID-19" OR "Corona")	0	0	0	0

Based on Table 2, the relationship between RO and SDGs only shows papers on keywords coded 1, namely keywords within the category "RO with SDGs in General", by bringing up 18 papers sourced from Science Direct. Of the 18 articles, no duplicates were found following duplication screening. Furthermore, for the code 2 keyword, namely the

relationship between RO and the SDGs one-by-one, zero papers were found in the output. This supports the statement that there currently exists no paper that specifically discusses RO with the SDGs theme. Furthermore, the output gain for code A and B keywords appears more diverse. The three digital libraries provided a total output of 22 papers for code A, and 9 papers for code B.

Based on the discussion, it can be concluded that RO has not been specifically related to SDGs and to COVID-19. Therefore, we decided to expand the keyword structure. This aims to retrieve a higher paper number output, so that the analysis in the systematic literature review is more diverse. In the next section, database mining is carried out with the link between Operations Research and Optimization Modeling (OROM) and SDGs. The result in Table 2 also shows the research interest in RO topics from Indonesian authors. This aims to reveal that interest in RO and SDGs topics is building in Indonesia.

4.2. Keywords Identification and Database Mining

The first step of the PRISMA method is the identification stage. By using a similar method as in Table 2, the keywords are obtained as in Table 3.

Table 3. Database mining of OROM and SDGs.

Identification (Step 1)						
Code	**Type**	**Keywords**	**Scopus**	**Science Direct**	**SAGE**	**Total**
A	OROM with SDGs in General	(“Operations Research” OR “Optimization Model”) AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”)	9	13	0	22
B	SDGs one-by-one	(“Operations Research” OR “Optimization Model”) AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”) AND (“No Poverty/Good Health and Well-being/Quality Education/Life Below Water”)	1	0	0	1
C	SDGs one-by-one	(“Operations Research” OR “Optimization Model”) AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”) AND (“Zero Hunger/Gender Equality/Clean Water and Sanitation/Decent Work and Economic Growth/Industry, Innovation, and Infrastructure/Sustainable Cities and Communities/Responsible Consumption and Production/Climate Action/Life on Land/Peace, Justice, and Strong Institutions/Partnerships for the Goals”)	0	0	0	0
D	SDGs one-by-one	(“Operations Research” OR “Optimization Model”) AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”) AND (“Reducing Inequality”)	1	0	0	1
E	SDGs one-by-one	(“Operations Research” OR “Optimization Model”) AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”) AND (“Affordable and Clean Energy”)	1	2	0	3
F	OROM with SDGs During COVID-19 Pandemic	“Operations Research” AND (“Sustainability Development” OR “Sustainability Development Goals” OR “SDGs” OR “SDG”) AND (“Pandemic COVID-19” OR “COVID” OR “COVID-19” OR “Corona”)	80	0	0	80
G	OROM with Developing Country	“Operations Research” AND “Developing Countries”	41	2	0	43
H	OROM in Indonesia	“Operations Research” AND “Indonesia”	34	0	0	34

4.3. Screening, Eligibility, and Included

The second stage of the PRISMA method is Screening, namely, duplicate screening and manual screening based on the title and abstract of each article. Duplicate screening is assisted by Mendeley software. In the fourth column in Table 4, it can be seen that there is a reduction in the number of articles that have been successfully checked for duplication. Screening titles and abstracts are filtered based on the categories determined by the researcher.

Table 4. Screening, Eligibility, and Included Step in PRISMA Method.

Code	Identification (Step 1) Total	Screening (Step 2)		Eligibility (Step 3) *	Included (Final Step) **
		Screening Duplicate	Title and Abstract Screening *		
A	22	18	19	5	1
B	1	1	11	1	0
C	0	0	0	0	0
D	1	1	11	1	0
E	3	3	1	1	1
F	80	56	21	8	1
G	43	35	11	3	1
H	34	30	6	3	0
TOTAL	184	144	80	22	4

Note: * Dataset 1 for bibliometric analysis, ** Dataset 2 for literature review.

Furthermore, the process continues with the third stage of the PRISMA method, namely, the Eligibility stage. This stage consists of reading the article as a whole, and verifying whether the article content specifically matches the topic of our review paper. If a full paper check has been carried out, then the selected articles enter the final stage, namely the "included" stage. The final stage, that contains the final article database in the form of ".bib", which database is used to prepare state-of-the-art tables, bibliometric maps, and other outputs on the RStudio software, and to analyze research gaps, will be explained in the next section.

Based on Table 4, it is shown that the 80 article databases obtained at the title and abstract screening stage were used to perform a bibliometric analysis using the RStudio software. This is because the database contains articles on various topics, supporting the variation of relationships between topics in bibliometric analysis. Furthermore, the database obtained in the final step is used to conduct a literature review. This is because a literature review is needed on specific articles to discuss the depth of the topics one-by-one. Table 4 is presented based on the steps in the PRISMA Method.

4.4. Bibliometric Analysis Using RStudio Software

The final database obtained from the PRISMA method, is the material needed by the RStudio software to provide output for analysis and discussion. Figure 2 presents the bibliometrix output diagram performed in this article. The diagram is divided into three general stages after total database mining: mining bibliometric data, analysis of bibliometric data, mapping the state-of-the-art, identification, and analysis of gaps and trends. This diagram is implemented in the following section. The topic of OROM with SDGs during the COVID-19 pandemic is used.

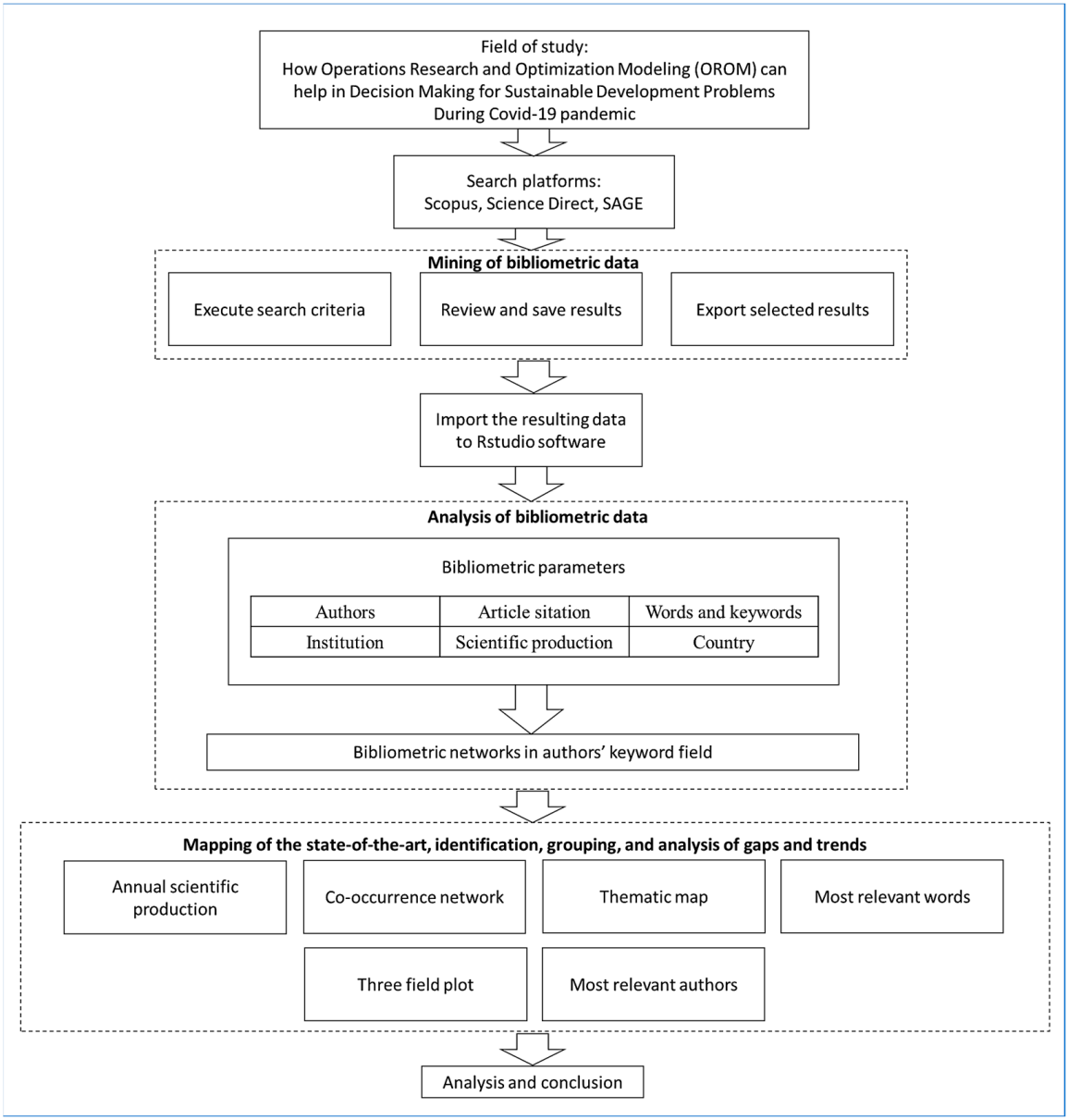


Figure 2. Bibliometric analysis output diagram.

4.5. SLR in RO/OROM with SDGs during the COVID-19 Pandemic

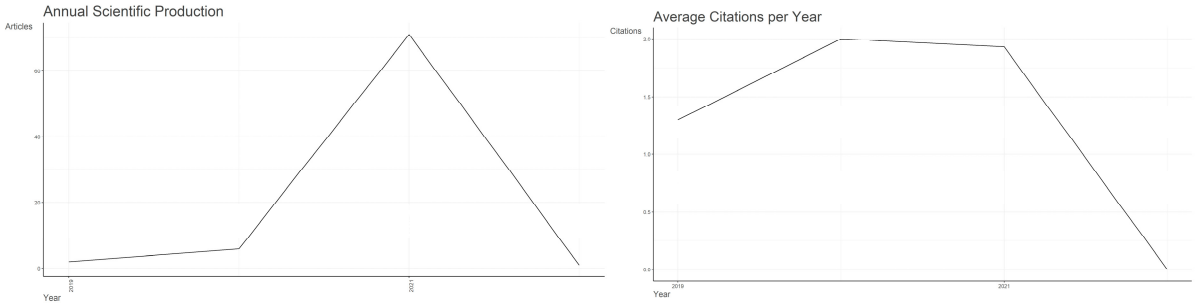
4.5.1. Data Identification

Data identification is the basic output produced by RStudio with the "bibliometrix" package. Data identification provides basic information about the final database of the articles entered. The topic of OROM with SDGs during the COVID-19 pandemic (keywords with code F), has as many as 80 database articles with a time span between 2019 and 2022. These 80 articles have average years from the publication of 0.112, average citations per document of 5.912, average citations per year per document of 5574, and the total consists of 8212 references. A total of 421 authors were involved, of which 71 wrote articles and the others wrote paper reviews. This data identification stage is the first step in the deeper analysis of the entire article in the following subchapter.

4.5.2. Articles' Evolution between 2019–2022

The second output produced by the RStudio software was the annual scientific production in Figure 3a, which displays the increase or decrease in the production of scientific

articles from the years 2019 to 2022. Based on Figure 3a, the year 2021 ranks the highest in terms of production of scientific articles, with a total of almost 70 pieces.



(**a**) (**b**)

Figure 3. (**a**) Annual scientific production, (**b**) average article citations per year.

This is possibly due to the COVID-19 pandemic, which began in late 2019, such that the researchers increased the number of papers written on the topic of OROM with SDGs during the COVID-19 pandemic.

Figure 3b shows the average article citations per year within the same period. Based on this figure, 2022 is the year with the highest average number of article citations, after previously experiencing a decline.

4.5.3. Authors' Analysis

To analyze the relevance of the authors of the 80 articles, a special analysis of the authors is required. This analysis is supported by subsequent outputs from the most relevant authors and top authors' production over time, as seen in Figure 4. Figure 4 presents the twenty most impactful authors on the topic of OROM with SDGs during the COVID-19 pandemic. The first nine authors were the most impactful authors, with two published papers each, while the other eleven each had only one published paper on a relevant topic. Figure 4 fulfills the 10 top global authors' production over 2019–2022. The productivity of the authors can be seen from the number of articles published successfully in the time interval. Based on Figure 4 the more articles published, the larger the circle size that appears.

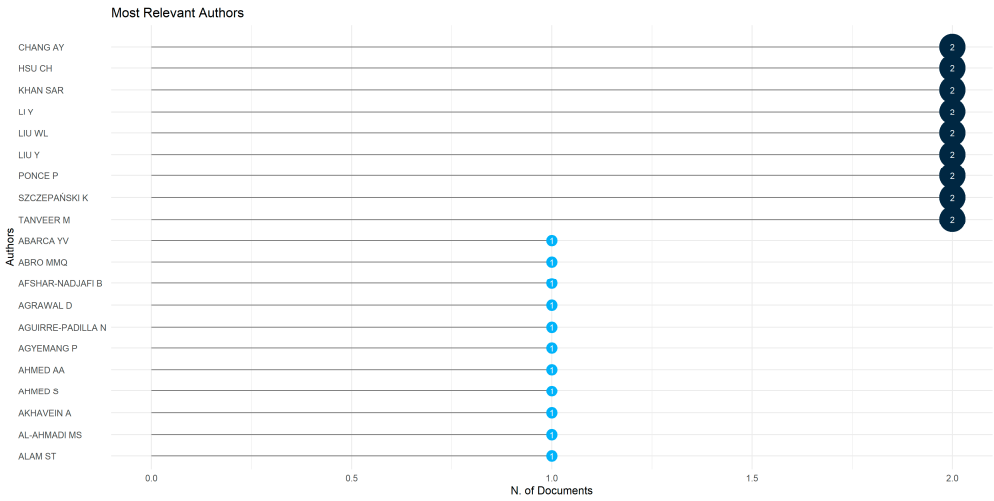


Figure 4. *Cont.*

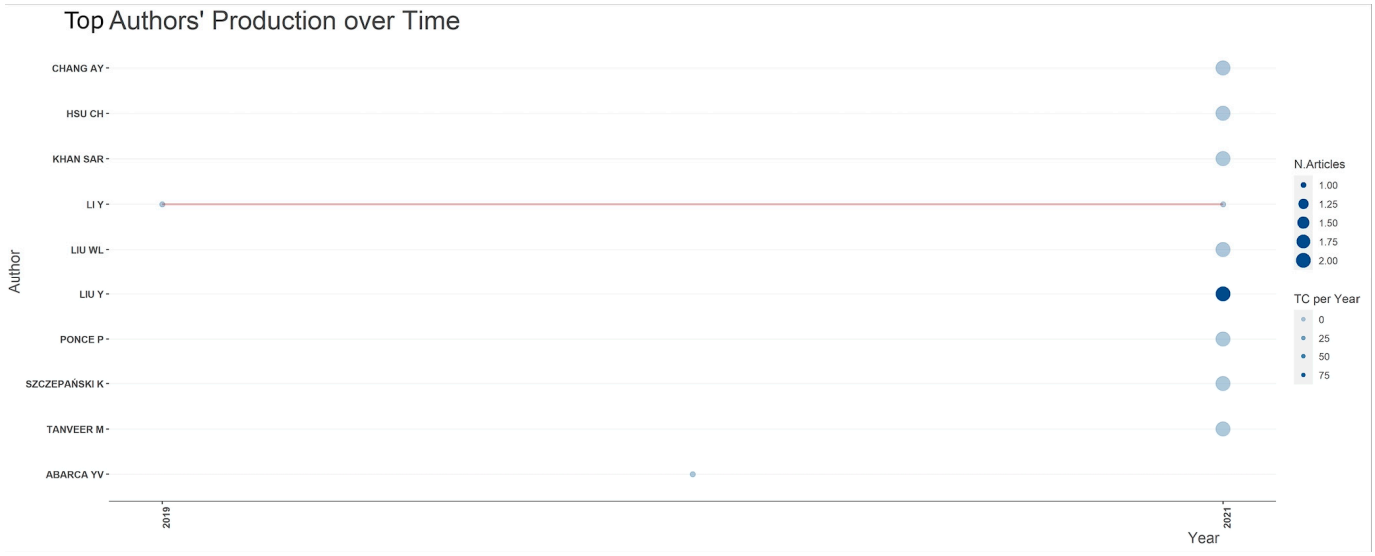


Figure 4. The most relevant authors and top authors' production over time.

After being evaluated, 8 circles in Figure 4 have the same size, with a description of each author publishing 1 article at that time. Therefore, all eight articles have the same level of productivity. In addition, the impact can be evaluated by considering the total citations per year. Based on Figure 4, the darker the blue, the more total citations were obtained. Liu Y has the darkest blue color.

4.5.4. Word Appearance Analysis

A critical follow-up analysis is related to developing the most frequent words. The output of the most pertinent words generated by the RStudio Software has three types, namely, unigram (maximum one word appears), bigram (maximum two words appear), and trigram (maximum three words appear). This study searches for the most frequent trigrams of words in the abstract field. The analysis of the relevance of words serves to see which keywords often and rarely appear, examine which keywords still have the opportunity to be developed in research, and assess which keywords have been utilized out in many studies.

Figure 5 provides the ten most frequent words on various topics. Sustainability and COVID-19 were ranked 1st and 2nd in the abstract, with 14 and 11 occurrences, respectively. Meanwhile, keywords regarding OROM have not been found to appear in 10 frequent words, thus prompting research of this matter.

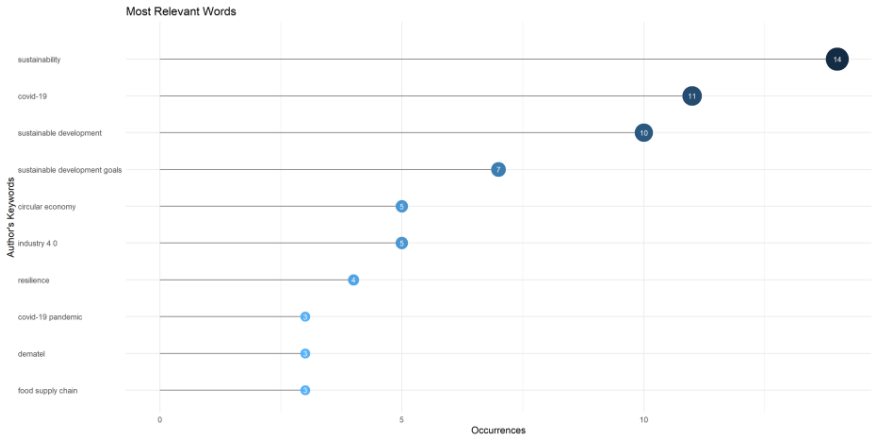


Figure 5. *Cont.*

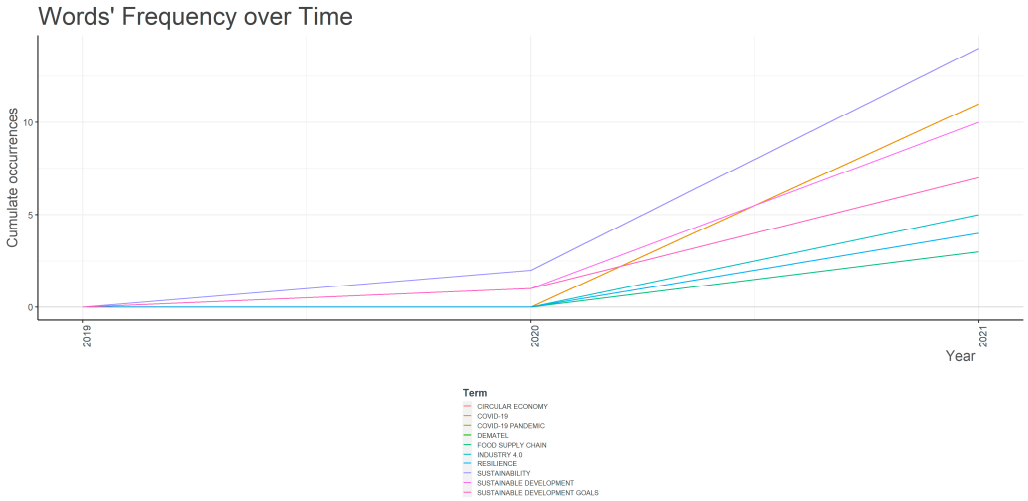


Figure 5. The most frequent words, and words' frequency over time in abstract fields.

A thematic evolution of the topics, as shown in Figure 6, can be determined, to present important information regarding the differences in subtopics by article authors based on clusters obtained in the 2019–2022 timeframe. The thematic evolution map is beneficial for researchers to analyze the development of topics in four different quadrants; these are identified based on the degree of relevance (centrality) plotted on the X-axis, and the degree of development (density) plotted on the Y-axis. Furthermore, centrality defines the interaction level of the inter-clusters. Precisely, centrality measures inter-cluster interaction, i.e., the extent to which a topic is connected to other issues. Furthermore, density measures the time when keywords in a particular cluster are linked, and thus a theme is developed.

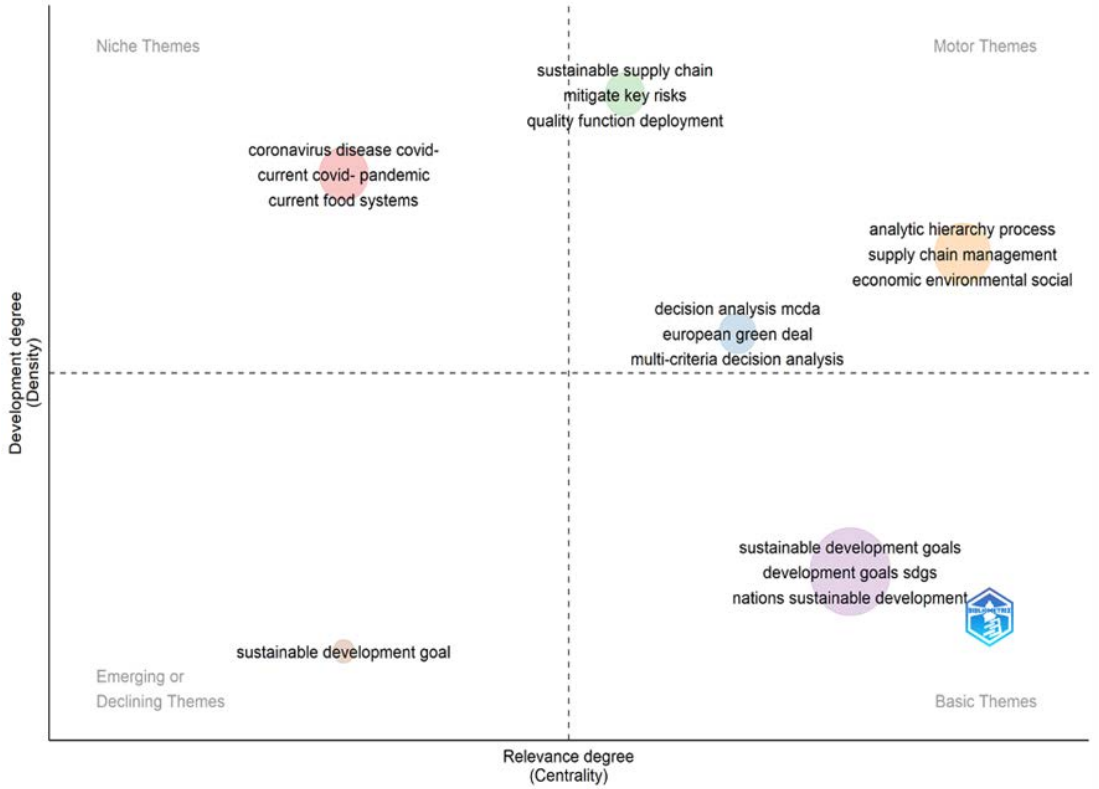


Figure 6. Thematic map.

In the thematic map, based on an explanation of the X and Y axes, it is known that the upper right quadrant contains topics with high centrality and density, which means these

topics can influence research and are well developed. The topics that are in the upper right quadrant position are in green cluster (sustainable supply chain, mitigate key risks, and quality function deployment), blue cluster (decision analysis mcda, european green deal, and multi-criteria decision analysis), and orange cluster (analytic hierarchy process, supply chain management, and economic environmental social). These nine topics are the most developed topics, with increasing discussion in journals and researcher interest in research in the 2019–2022 timeframe.

The lower right quadrant includes issues with strong centrality (i.e., able to control the other problems) but weak density (i.e., not well developed). The topics that are in the lower right quadrant position is purple cluster (sustainable development goals, development goals sdgs, and nations sustainable development).

The lower left quadrant contains topics with weak centrality and density, meaning that these topics are less able to influence research and are not well developed. Finally, the upper left quadrant contains the opposite issue to the lower right quadrant. The topics that are in the lower right quadrant are coronavirus disease covid, current covid pandemic, and current food systems (pink cluster).

Through this explanation, based on Figure 6, it can be observed that emerging topics such as sustainable development and sustainable supply chain are in the upper right quadrant, which means they can influence research and are well developed.

4.5.5. Bibliometric Map Analysis

The last important output that needs to be discussed is the co-occurrence network in authors' keywords, as shown in Figure 7. Five keyword clusters were obtained based on the resulting color: purple, brown, orange, green, and blue. The cluster provides information on the grouping of previous research topics in the 80 selected articles.

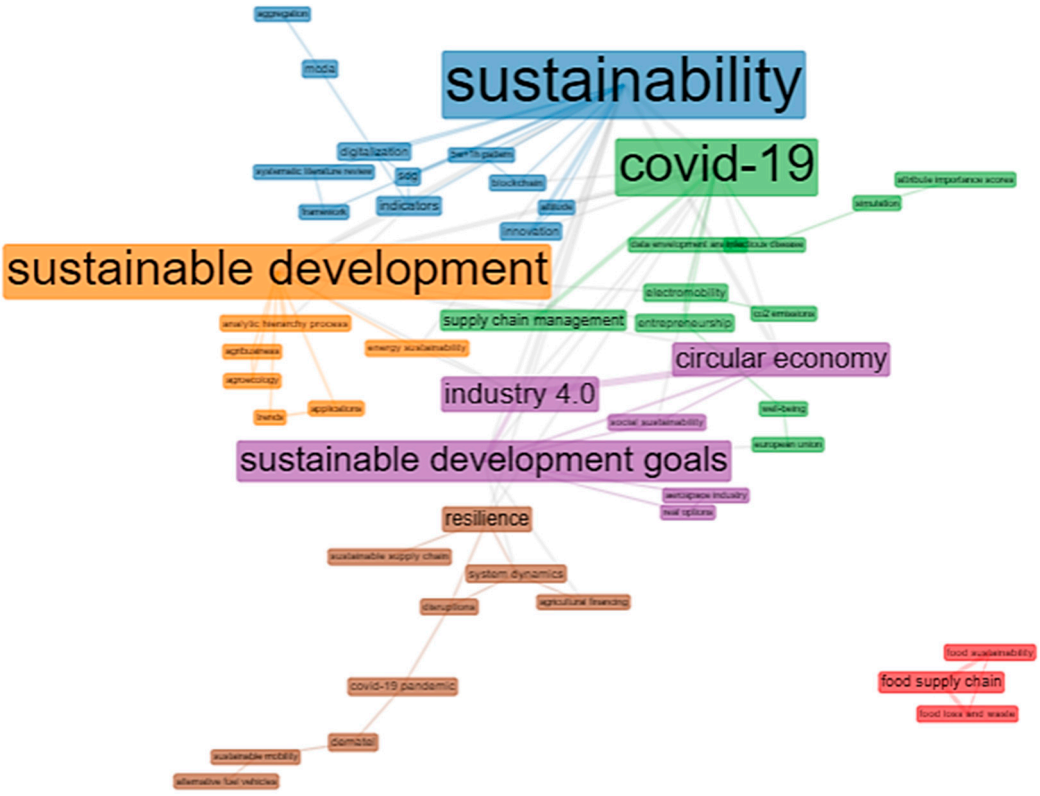


Figure 7. Co-occurrence network in authors' keywords.

From the mapping results in Figure 7, it is found that the keyword "COVID-19" is already related to "sustainable development goals" or "sustainability". This means that there is already at least one article discussing a related topic. However, the absence of

keywords related to OROM, such as "optimization modeling", "operations research", "decision making", or methods related to OROM, strengthens the argument that there currently exists no research into how Operations Research and Optimization Modeling (OROM) can help in decision making for sustainable development problems during the COVID-19 pandemic. Therefore, the research and the focus of this review paper have not yet been widely carried out, thus presenting a new opportunity for implementation.

5. Discussion

This section contains discussion of the results and how they can be interpreted, from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted. Discussions are also presented to answer the RQ stated in Section 1.

5.1. State-of-the-Art and Research Purposes on RO/OROM and SDGs during the COVID-19 Pandemic

The results from Dataset 2, namely, a database containing articles selected in the final stage, can be seen in Table 5. Articles in Dataset 2 were published within the 2019–2022 timeframe.

Table 5. Results from Dataset 2.

No	Authors	Type of SDGs	Method in Operational Research and Optimization Modeling	Problem
1	Ozkaya and Erdin (2020) [37]	SDGs and Global Forest Goals of the United Nations Strategic Plan for Forests 2017–2030 targets	TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje, meaning Multi-Criteria Optimization and Compromise Solution), which are among the most used multi-criteria decision-making methods	A need for urgent action plans at all levels, to ensure sustainable forest management and policy collaboration among all stakeholders, in order for forests to continue to serve our ecosystem and life in the future
2	Charurat et al. (2020) [38]	Pregnancy planning choices (SDGs no 3)	Multi-country, quasi-experimental three-year operations research study in Brebes and Batang Districts of Indonesia and Meru and Kilifi Counties of Kenya	Global evidence suggests many postpartum and postabortion women have an unmet need for family planning (FP) after delivery, or receiving care following loss of a pregnancy
3	Caglayan et al. (2021) [39]	Optimally provide ecosystem services that are consistent with, and based on, Sustainable Development Goals (SDG)	Allocation optimization model through the development of coefficients and constraints	Determine the location and resolve trade-offs in the management of forests according to ecosystem services
4	Haq et al. (2021) [40]	SDGs in general	Neutrosophic programming (NP) that simultaneously optimized gross domestic product (GDP) growth, electricity consumption, and greenhouse gas (GHG) emissions, and solved with the goal programming (GP)	Explore the concept of neutrosophic programming (NP)

This section intends to answer the first research question: How the state-of-the-art in RO/OROM-SDGs is determined to formulate novel and new research objectives? Based on the results of Dataset 2, it can be seen that all articles discuss different SDGs cases, and always relate them to operations research, optimization modeling, or decision-making methods. However, there are no articles that use robust optimization methods for solving SDGs problems during a pandemic, thus supporting how new it is to have people conducting research on this topic. From SLRs that we conducted, we can state that the purpose of conducting research on RO and SDGs during the COVID-19 pandemic, is to handle the data uncertainty which is involved when a decision must be made.

5.2. Which SDGs Types of Problems Have Been Modeled Using RO/OROM?

5.2.1. Recent Results RO for SDGs No 2

As we see in [40], a development on [41] created an optimization model for supply chain problem with two objective functions: minimizing logistics costs and maximizing product suppliers for all demand. Article [41] addresses three additional scenarios that differentiate types of distribution between producers and consumers, between Regional Food Hubs (RFH) and consumers, and their aims. The supply chain optimization model is related to the distribution of vegetables, rice, and eggs between producers, RFH, and consumers, in 37 cities affected by COVID-19 in West Java Province.

Further, article [42] conducts and uses a nominal optimization model sourced from [41], with some changes. Then, the model is changed to a Robust Optimization model with uncertainty parameters, which are discussed later. There are four differences between [41] and [42]. First, the commodities used in [41] are agricultural processed products, namely sugar and cooking oil, while in [42], rice, eggs, and vegetables are involved. This is because sugar and cooking oil are the most influential agricultural processed products besides the main staple food of Indonesian people, which is rice. Second, the Linear Programming method was used in [42] for solving the problem, and it has one objective function, that is the first objective function that maximizes the demand for the product. Meanwhile, the reference article [42] uses the lexicographic method, because it has two objective functions.

Third, the research of [41] was carried out on a smaller scale, namely the districts in Bandung, while in the reference article [42], the research was carried out on a larger scale, namely cities in West Java Province, so that the name Regional Food Hubs (RFH) was changed to Local Food Hubs (LFH). Fourth, this study uses two scenarios, large-scale social distancing, and partial social distancing. Therefore, the secondary data used in the study of [42] are clearly different from the data of [41], on agricultural processed products of sugar and cooking oil obtained from various sources.

In this problem, in changing the nominal optimization model to a Robust Optimization model, the parameters that are uncertain are the demand for products in the consumer zone and the production capacity in the production zone, because the amount of demand and capacity of a product will change, depending on the needs of consumers and because of the limited movement of consumers in the production zone. Limited distribution of agricultural processed products, the slowdown in the production process, and changes in the supply chain system caused by the COVID-19 pandemic, are also causes for the uncertainty of capacity and demand for a product.

5.2.2. Recent Result on RO and SDGs No 11 during the COVID-19 Pandemic

Recent results on RO and SDGs No 11 show that the use of robust optimization for uncertain land-use allocation problems with box uncertainty are as shown in [43]. A certain spatial optimization model for land-use allocation is formulated. The difference is that the Robust Optimization model in this paper is performed using an ellipsoidal and polyhedral uncertainty set. Assume that the uncertainty data are benefit and acquisition cost. The robust counterpart is formulated when the uncertain benefit and acquisition cost lie within two uncertainty sets, i.e., ellipsoidal uncertainty or polyhedral uncertainty.

5.2.3. Recent Results on RO and SDGs No. 11 during the COVID-19 Pandemic

The change in peoples' behaviour during the COVID-19 pandemic constitutes the transformation from conventional trade to online trade. We recall a systematic literature review on adjustable robust counterparts for an internet shopping optimization problem by [44], the adjustable robust counterpart optimization model for the internet shopping online problem in [45], and Bender Decomposition for solving adjustable robust counterpart optimization model for the internet shopping online problem in [46].

6. Conclusions

In this review article, we present a systematic review with the topic of Systematic Literature Review on How Robust Optimization can help in Decision Making for Sustainable Development Goals (SDGs) during the COVID-19 pandemic. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) method is used as a protocol to describe article selection criteria, search strategies, data extraction, and data analysis procedures proven to improve the quality of literature review. We used a variety of keyword combinations of Robust Optimization (RO) and SDGs from three online digital libraries, namely Scopus, Science Direct, and SAGE. After all the PRISMA method protocols were carried out, RO has not been specifically related to SDGs and to the COVID-19 pandemic. Therefore, we decided to expand the keyword structure, with the link between Operations Research and Optimization Modeling (OROM) and SDGs. Furthermore, the absence of keywords related to OROM, such as "optimization modeling", "operations research", "decision making", or methods related to OROM, strengthens the argument that there is no research into whether Operations Research and Optimization Modeling (OROM) can help in Decision Making for Sustainable Development Problems During the COVID-19 Pandemic, as well as RO. It is clear that RO and OROM play important roles in decision making for SDGs problems. This shows us that in the future, the research on SDGs fields can be approached by OROM.

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