Indonesian Journal of Electrical Engineering and Computer Science
Vol. 26, No. 2, May 2022, pp. 1050~1059
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v26.i2.pp1050-1059

Metaheuristic nature-inspired algorithms for reservoir optimization operation: a systematic literature review

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Article Info

Article history:

Received Jul 3, 2021
Revised Feb 25, 2022
Accepted Mar 24, 2022

Keywords:

Metaheuristic
Natural inspired algorithm
Optimization
PRISMA
Reservoir optimization operation

ABSTRACT

The purpose of this systematic literature review (SLR) article is to discuss the findings of the state-of-art metaheuristic nature-inspired algorithm (MHNIA) in reservoir optimization operation. The rationale of this approach is to elucidate the optimal way as decision making that implemented MHNIA for several complex problems in reservoir optimization operation. Commonly, the metaheuristic optimization algorithm has always been used in hydrology field, especially in reservoir optimization. Hence, this presented study reviewed a considerable amount from the previous studies of commonly nature-based optimization algorithms applied in reservoir operations. Hence, preferred reporting items for systematic review and meta-analyses (PRISMA) has been used as guidance. The source was utilized from two primary journal databases: Scopus and web of science. According to the proposed search string, the findings managed to express into nine main themes which are optimize in water release, optimize reservoir operation problems, optimize hydropower operation, optimize condensate fluids in reservoir storage, optimize water pumped storage, optimize water quality control, optimize system performance operation, optimize water demand and optimize reservoir control as flood preventing. Overall, 24 articles that passed the minimum quality were retrieved using systematic searching strategies.

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1. INTRODUCTION

Most previous literature searches focus on non-methodological articles that regard the better's option to situate the studies within the existing knowledge. However, systematic literature review (SLR) proposed introducing extensive searching methods, predefined search strings, and standard inclusion in the literature search world are more robust evidence [1]. SLR allows ascertaining the pattern of prior results, comprehending the depth, details of the existing knowledge, and identifying the gaps in further exploration. With presenting in several advantages compared to non-methodological review method such as its abundant unique procedures, reviews process can be strengthened via a transparent article retrieving, more prominent wider of the research area, SLR also able to encourages the researchers to look for studies outside their subject and can control the bias articles.

SLR is an essential building block for knowledge advancement especially in sciences [2]. Examples of studies that applied SLR to address their new finding are the detection of medical diseases using particle swarm optimization (PSO) algorithm [3]. Meanwhile others studies applied SLR to find the impact of climate change in Asia Pacific regions [4]. Besides that, the eye-opening article title's '*mirror-mirror on the wall, what climate change adaption strategies are practiced by the Asian's fisherman of all*?' also proof that their finding from SLR able to led the recommendations for future studies by listing the activities among fisherman during climate change [5].

During the last two decades, optimization methods based on a metaheuristic nature-inspired algorithm (MHNIA) have become attractive to hydrologists to explore as better alternative decision-maker. MHNIA describe as a scientific method to solve the problem, indeed a nature-based phenomenon. This incidental method is utilized widely to elucidate the optimal way of decision-making for several complex optimizations, especially in engineering applications. In optimization, the studies from [6]–[8] prove that the metaheuristic nature-inspired algorithms were able to give a tremendous and relevant to be applied in variant fields. Therefore, to understand the interactives between reservoirs operation that need to be optimizeded, the searching suitable literature review using SLR need to be conducted in-depth observation.

Reservoirs play a vital issue in daily life applications. Besides maintaining and supplying hydroelectricity power, it is also essential to manage the effectiveness of reservoir operations while keeping them secured. Lately, most of the studies have implemented metaheuristic optimization algorithms to determine the optimal solution in reservoir operations. However, with the credibility of nature-based inspired, it became more popular to be implemented.

The United Nations world water development report 2018 demonstrates the natural-based solutions (NBS) to address the world's water challenges while delivering the additional benefits in sustainable development. NBS is the concept that describes the pattern of water resources management in various regions. Therefore, most researchers realize that this NBS can give unprecedented changes in sustainable development [6]. In multiple applications of NBS, it has been proposed in many pieces of literatures studies and implemented into real-world applications [9].

Many researchers in literature have used NBS state-of-the-art algorithm to solve the optimisation problems such as [10]–[15]. The contribution of this study is to provide a comprehensive SLR on MHNIA with their variations in reservoir optimization operation. The proposed literature search generated an idea to present the new finding to recognise the recent pattern studies related to the reservoir's optimization operation area. These proposed ways ensure the optimality of these nature-inspired algorithms to explore the selected search space with the progress in particular generations time duration, which the articles collected from 2015 to 2019.

The main concern terms used in this systematic review are identification, articles screening, articles eligibility, and database use. The selection of articles in this SLR is the main apprehensive since the peer review articles can deliver more understanding for future attention related to the nature-inspired optimization algorithm. Hoped the findings from this study encouraged the new researchers to recreate the new gap investigation to improve the understanding and evaluate the scope of related information in the future.

With that, the development of this SLR is according to the main research question whereby; what are the recent pattern studies of reservoir optimization operation that used metaheauristic nature-inspired algorithm (MHNIA) used in reservoir operation optimization?. The most concern is about 'what's' are the primary concern on reservoirs operation problems that applied the nature-inspired algorithm in solving the issues with giving optimal results and increasing the stability in their operation. The aim is to fill the gap by review the previous studies systematically in attempt to acquire more understanding of recognizing and describing the pattern of resevoirs operation problems.

Presented structures in this article are shown in section 2 which introduced the methodology process in searching the papers. In contrast, the following section presents the approach to answer the research question that formulated by recent studies according to the selected years from 2015 to 2019. The third section is conducting a systematic literaruture review and a structure of scientific literature to differentiate selection and evaluate significant research on metaheuristic nature-inspired algorithms against reservoir optimization operation. The last section discussed about the recommendation for future study from these findings.

2. MATERIALS AND RESEARCH METHOD

This study aimed to identify the state-of-the-art and potential pattern of reservoir optimization operation problems according to the techniques which implemented metaheauristics natural-inspired algorithm. The research question is "What are the state-of-the-art patterns of reservoir optimization operation problems that used metaheauristics natural inspired algorithm as their decision-maker?". This section explains the four main sub-sections, including PRISMA, resources, systematic review selecting process

(identification, article screening, and article eligibility) and data abstraction analysis employed in the current research Figure 1.

2.1. PRISMA

Preferred reporting items for systematic reviews and meta-analyses (PRISMA) is a standardized published template to conduct a systematic literature review. Generally, standards publications require the authors' guidelines with the necessary information to evaluate and examine the quality and rigidity of a review's articles [16]. Based [17], the importance of developing the systematic literature review using PRISMA can provide insight into the ability to recognize a target condition, provide estimate test performances, allow comparisons, reduce bias and facilitate to identifying the sources of variability. Moreover, to provide a more comprehensive explanation and understanding, elaboration, and explanation in PRISMA are suitable processes that can be applied [18], PRISMA is also ideal for environmental management due to the clearly defined and precise search term conducted. Using the PRISMA, allows simplifying all of the information concerning future MHNIA in management reviews while determining the inclusion and exclusion criteria.

2.2. Resources

The review methods in this systematic literature review article were conducted in two primary databases, Scopus and web of science (WoS) considering that both databases are robust. Specifically, Scopus Web of Science indexes a total of 2123 journals related to the reservoir optimization algorithm in various fields, while Scopus indexes number 2631 journals all described in reservoir optimization algorithm in environmental science, engineering, earth and planetary sciences, agricultural and biological science, energy, social science, computer science, and mathematics fields. However, it should be noted that no databases are comprehensively perfect, including Web of Science and Scopus.

2.3. Systematic review process for articles selection

This section aims to identify the state-of-the-art and potential pattern of reservoirs optimization operation based on MHNIA. There are three phases in this process: identification, article screening (involve inclusion and exclusion) and article eligibility.

2.3.1. Identification

The identifying process of the narrative title is based on search engines. There are required to considers a few spelling to capture the variation of terms [19]. The first stage in identification is finding keywords followed by searching the related and similar words based on encyclopedia, thesaurus, and past studies. The terms used to find the relevant articles were developed in January 2020 after determining relevant keywords (Refer Table 1). From this, the articles were success retrieved 265 from both databases. For manually searching based on similar keywords to another database are six articles. Therefore, 271 articles were rescued in the first stage of this systematic literature review. The main Boolean TITLE-ABS-KEY used for Scopus and TI (searches based title, abstract, author keywords, and keywords plus) for WoS.

Table 1. The search strings

Database	Search string
Scopus	TITLE-ABS-KEY **((**"reservoir optimization" OR "reservoir optimization algorithm" OR "river basin") AND ("metaheuristic optimization" OR "nature-based optimization" OR "optimization"))
Web of Science	TI = (("reservoir optimization" OR "reservoir optimization algorithm" OR "river basin") AND ("metaheuristic optimization" OR "nature-based optimization" OR "optimization"))

2.3.2. Article Screening

In this screening stage, based on [20], [21] suggested at least two reviewers' independent approaches to evaluate the similarities in the selected studies with established literature review inclusion and exclusion benchmarks. The central concern appraisals in this systematic review article are based on the title, abstract of the studies, and keywords. Table 2 describes the way of selective inclusion and exclusion criteria. 271 were screened based on several inclusion and exclusion processes in this case. The first selection criterion in inclusion is based on articles paper with empirical data and review articles in years range in a specific period (2015-2019) was chosen for timeline. The important things are all articles published in environmental science, engineering, computer science and mathematics to increase the possibility of retrieving related articles. Overall, all 121 articles were excluded based on these criteria as shown in Table 2.

Table 2. The inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Publication timeline	2015-2019	2014 and before
Document type	Article (with empirical data) and review articles	Conference proceeding in book, book series and books
Language	English	Non-English
Nature of study	Focus on methodology and aimed	Not focus on methodology
Subject area	Reservoir optimization operation based on metaheauristic nature inspired algorithm	Others than reservoirs optimisation operation application and non-nature inspired optimisation based

2.3.3. Article eligibility

The totals of 150 articles were selected in this eligibility stage. The main essential terms are titles, abstracts, and the main contents of all examined articles to fulfill the inclusion criteria to achieve the objectives in this article. Subsequently, 126 were excluded due to the unsimilarities subject focusing areas, not empirical data, not focused on reservoir optimization operation, and not related to the nature-inspired optimization algorithm. Finally, a total of 24 articles remained ready to be analyzed as shown in Figure 1.

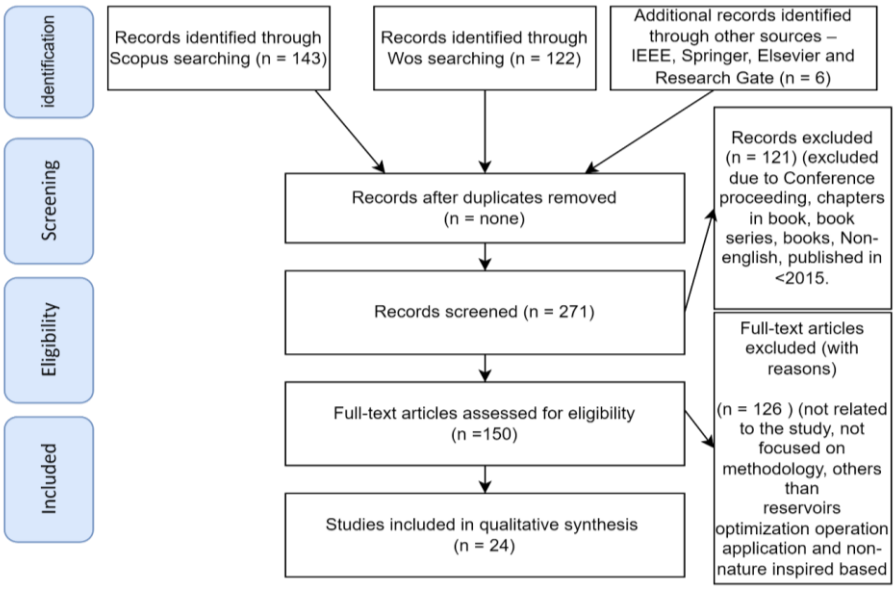

Figure 1. Flow diagram of the study [17], [22]

2.4. Data abstraction and analysis

This systematic literature review article accomplished an integrative review and qualities from all selected information. The process of developing data abstraction and analysis of themes based on thematic analysis. This part is essential for analyzing and comparing all related literature instead of summarizing it [23]. For the first stage in this section, the development of sub-themes based on compilation the informations. The main concern on 24 selected articles was analyzed and then extracted to answer to the research question. The definition variation was created for the second phase to identify the more related ideas, themes and synonyms to get more related information [19]. For last phase is the process of generating the result. These present findings are according to the quantitative technique. Reading 24 articles thoroughly, particularly in abstract, methodology, and results, have produced a thematic analysis that identified the themes. The selected thematic analysis is considered the most effective synthesizing process in research design [24]. The first process in the thematic analysis is to generate the themes by identifying the pattern of development among the abstract information from all reviewed articles. Any related abstract will group into one theme according to the most recent pattern investigation in reservoir optimization within 2015-2019.

3. RESULTS

The systematic literature review obtained 24 selected articles according to the proposed search string in 2015-2019. The selection of these themes is based on the recent application of reservoir optimization operation by using MHNIA within the years 2015-2019. Based on this analysis, the result produced nine themes related to reservoirs optimization operation that traces based on their methodology

using MHNIA. Even there is also a less relevant theme found which condensate for fluids in the reservoir. This article is still counted because of using MHNIA in their study. There are many studies found that implemented MHNIA in various fields. But in this article, with specific time and search string, produced a total of nine themes that related to the operation of the reservoirs that can use as future references.

a) Water release

Water supply is among the primary purposes of developing reservoirs. Due to demand, the standard operation policy (SOP) of water supply is one of the most straightforward policies considered in managing the water release. As referred in the SOP, the scheduling for water release is based on the standard demand. All of the water in the reservoir will be released in a given period and does not preserve water for future requirements called demerit SOP. Most acceptable policies apply space rule, linear decision rule, and hedging rule and pack rule. However, in water release optimisation operation that applied MHNIA, the study from [25], used genetic algorithm (GA) to generate the scheduling optimal water release policy called binary standard operation policy for hydropower generation (BSOPHP), continuous standard operating policy for hydropower generation (CSOPHP) and standard heging policy for hydropower generation (SHPHP) meanwhile study from [26] applying stochastic dynamic programming (SDP) in developing the water release scheduling.

b) Reservoir operation problems

Besides that, another significant challenge and difficultiy in a recent study found in reservoir optimization are solving the optimal operation rules. The conflict is related to the major problems in reservoir operations. Some studies call it a conflict evaluation index (CEI) [27] applied to solve the general issues in multi-reservoir operations. Among the technique in MHNIA that are often encountered applied in these problems are by using the bat's algorithm (BA) [28], ant colony optimization (ACO) [29], weed optimization algorithm (WOA) [30], firefly optimization algorithm (FOA) [31], water cycle optimization (WCO) [32], cat swarm optimization algorithm (CSA) [33], combined WOA with PSO [34], borg optimization algorithm (BOA) [35], strawberry optimization algorithm (SOA) [36], watershed optimization algorithm (WOP) [37] and the last one is using shark optimization algorithm (SHOA) [38]. The grasshopper algorithm, Moth-flame algorithm, grey wolf optimization within PSO, and GA also solved the reservoirs operation problems [7]. Remarkably, most of the techniques from MHNIA applied to solve the problems in multi-objective problems. It is worth mentioning that this selection theme will be significantly attractive to new researchers who emphasize solving multi-objective problems. It is proof that the application of MHNIA can perform an optimal operation rule within reliable, effective, and robust [39].

c) Optimal hydropower operation

Lately, controlling and managing the hydropower operation has become one of the most critical tasks, even during the peak season of floods or drought season and experiencing a rapid growth period throughout the world in recent years [40]. Due to the expanding system scale and demand of complexity operation, most of the studies present multi-objective optimization to solve their problems. The feasibility to solve a multi-objective hydropower reservoir operation indicated that able to achieve approving a good performance in several different cases. This is why the application of MHNIA for maintaining generation hydropower source from reservoir also got deliberation. Therefore, among techniques that classified to solve this problem which included PSO [41], FOA [42], crow optimization algorithm (COA) [43], charged search (CS) Algorithm [44], kidney optimization algorithm (KOA) [45] and GA [25].

d) Condensate for fluids in reservoir

Between 2015 -2019, there is a minimal study focused on this condensate reservoir optimization. Due to the complexity factors to solve the related problems, MHNIA is one of decision-makers in evaluating the potential of production boost. A study found that using a new development of monkey-krill herd hybrid (MAKHA) merging with other natural-inspired optimization algorithms as decision-makers in solving critical problems in multicomponent fluids in reservoir [8]. The resultant from the study shows the capability of MHNIA which can solve real-time and multicomponent reservoir operation problems.

e) Water quality control

A minimal study was found in 2015–2019 using the proposed search string to solve water quality control. In reality, water quality control is becoming the most critical issues due to high demand, extreme development, and undoubtedly strong effects on human life and the natural environment. Various characteristisc of water in reservoirs needed to identifed specifically in attempt to develop an optimal water resources management plan. Therefore, the main water element in the reservoir is quality needs to be

appropriately evaluated. To provide an innovative water quality assessment in reservoir optimization operation, a study proposed data mining machine learning to solve the operation cost and reduce the complexity of measuring parameters. The finding in the study proves that the applications of MHNIA are the most effective for the first stage of baseline analysis and yield better performance of all selected individual model tests. Thus, the recommendation from the authors, with simple data analytics can be used as prediction models for water quality control [42].

f) Optimal system performance

Difficulties in water allocation caused by increasing demands and scarcity of water resources are essential in achieving sustainable development and maximizing benefits. All existing system such as hydraulic structures around the reservoir plays crucial roles in water resources management. Besides that, the structures measures approach around the reservoir also needs to be considered system performances. A study found an implemented artificial bee colony (ABC) technique as their optimizer solution to evaluate the system performances analysis of reservoir optimization [46]. This study's findings were presented based on reliability, vulnerability, and resiliency. However, limited results focus only on system performance with a single-optimizer algorithm. Most discoveries also mixed their proposed method with others well-known developed techniqeus in MHNIA.

g) Optimal water pumped storage

The following themes analyzed in this systematic literature review are optimization for water pumped storage from the reservoirs. In a previous study, it is also called pumped water storage (PWS). The effectiveness of water pumped operation is based on competence in their operating rules. A study found managing average by searching the variability of streamflow in China. The main objectives function in this study is to minimize the water shortage index (WSI) to avoid drought while maximizing the net revenues of produced and consumed energy. By proposing these multi-objective optimization problems, the implemented method are proven effective for developing an optimal operating rule, rather than improving water diversion performance, significantly when the highest demand water supply while decreasing the energy consumption and spill volumes [47].

h) Optimal human water demand

Several countries face increasing water demand and hence growing competition for water. This situation is a conflict that always needs to be concerned. From hydropower generation, food production until agriculture production, a properly managing reservoir operation is always eye-catching study. There is a need to find a suitable solution for a real-time or simulation model to predict a real-life situation. A researcher from China executed the Sanhekou's reservoir as their platform in managing water allocation and human water demand. The proposed simulation model integrates starting from calibration, validation, and application by using MHNIA, which Cuckoo searches [6]. The authors in this study are satisfied with the results that proven to feasible change the water transfer process from the human demand side takes more priority, while the the natured-based side which river protection takes precedence that significant close to reality. Therefore, in this case, the application of MHNIA is also possible to find the optimal solution among the several potential problems, either in an actual situation or simulation model.

i) Flood preventation

Flooding can damage property, additional in extreme events and losses of life. The risk of loss could be eliminated if the structural measures around the reservoir could be properly managed. Besides that, for effectiveness of flood controls also depends on the efficiency of reservoirs operation strategies [48], [49]. The huge economic impact can also happen due to flood if there is involved in structural or residential areas. Therefore, properly managing the reservoir will be an essential point in water resources management and resource allocation [50] to decrease massive floods. As examples in MHNIA, studies using a memetic immune optimization algorithm (MOA) are being used as decision making in flood control [51]. A study in 2017 also proposed PSO as an optimization platform to improve social well-being in general while simultaneously the flood threats [52]. By implementing multi-objective optimization, this proposed study's result indicated better performances than historical data operation. The proposed technique is relevant to be implemented in the complex multi-objective optimization and solve other systematical engineering problems.

j) Summary

According to the pattern studies within 2015-2019, the thematic analyses produce nine themes using the proposed search string. Figure 2 describes a concise explanation of variant of reservoir operation optimization using MHNIA in year's publications ranges within 2015-2019. The comparative description of reservoir optimization operation and application of MHNIA can see in Table 3. Most studies found that using

MHNIA in their research is to solve the general issues in reservoir operation problems, followed by optimal hydropower operation. The findings from this systematic literature review show that there are minimal studies found that used MHNIA in solving their research, especially in optimizing water release, optimizing water demand, optimizing pumped for water storage, optimizing system performance, optimizing flood preventing, optimizing water quality, and the less relevant theme is optimizing in condensate reservoir fluids. Condensate reservoir fluids still are counted due to their method also implemented MHNIA. There are well-defined gaps to be examined since reviewing highly qualified publications only from 2015-2019. This reason can develop hypotheses that could be investigated in future works for the researchers who anticipated contributing to the reservoir optimization by using MHNIA.

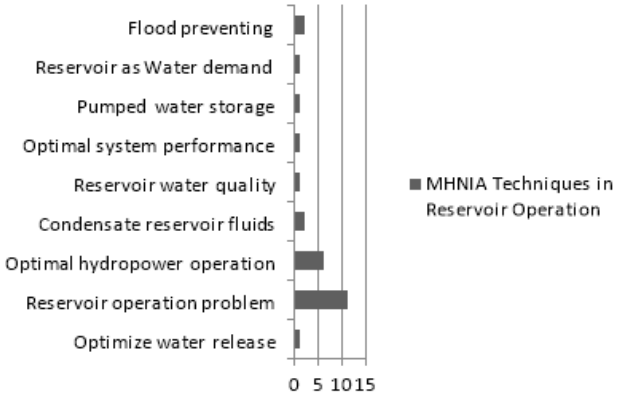

Figure 2. Summaries of final themes

Table 3. The summary of implemented MHNIA approaches in reservoir optimisation operation

Application/t themes MHNIA	Optimize water release	Reservoir operation problem	Optimal hydropower operation	Condensate reservoir fluids	Reservoir water quality	Optimal system performance	Pumped water storage	Reservoir as water demand	Flood preventing
BA		/							
PSO			/						
ACO		/							
WAPSO		/							/
WA		/							
FOA		/	/		/				
MAKHA				/					
CS			/				/	/	
WCO		/							
CSA		/							
COA			/						
ABC						/			
BOA		/							
SOA		/							
WOP		/							
KOA			/						
GRS,				/					
MOT.GW, PSO & GA									
GA	/		/						
SHOA		/							
MOA									/

4. RECOMMENDATION

This SLR presents the state-of-the-art published articles that implemented the MHNIA as solving the problem related to reservoir optimization operations. Findings the solution using metaheuristics involve a concession between the speed of finding and potential to solve the reservoir optimization operation problems. These findings suggested several recommendations and considerations for future study whereby more studies are needed to review the application of the natural-inspired algorithms in flood mitigation and prevention due to the crucial issues and limited study from that. The systematic review process may help revealing future studies to be considered in conducting more other studies. The application of these natural-inspired

optimization techniques can be found in various fields. However, to overcome the challenges of creating an existing nature-inspired algorithm, future studies may focus on the new improvement of the standard algorithm into combining or hybrid methods to identify the weakness and strength of the algorithm itself.

5. CONCLUSION

Recently, literature on the application of MHNIA reflects a basic understanding on how they used these techniques to solve problems and decision-makers. Rapid development in these optimization techniques in frequent hydrologists and water management resources has successfully in overcome the shortcoming of traditional approaches. Additionally, almost some methods in MHNIA are relatively well-known not only in computer science fields but also in different fields. MHNIA are reasonably simple, flexible, derivation-free mechanism and local optima avoidance. MHNIA is highly appropriate for real problems with expensive or unknown derivation information.

With that, the findings' theme presented based on techniques of MHNIA is performs as a pattern of current studies about reservoir optimisation operation. The themes offer the strategy to solve the problems obtained from the state-of-art reservoir optimization operation that can be used in different situations as pre-planning in the future. These themes play as primary purposes of creating the reservoirs by presenting a simple objective function. Most of the studies found their results effectively and successfully fulfilled their objective function. The techniques is used in the most critical issue since so many developments and leisure industries develop nearby the reservoir that will affect the balance of the ecosystem itself. These are suitable alternatives that deserve to highlight in finding the optimal solution as precaution to anything destructive. End of the word, the implementation of MHNIA in sustaining the reservoir operation can provide an optimal solution significantly in reservoir optimization operation problems. For future work, this finding can lead the new researchers to find the state-of-art related study about reservoir operation and find a gap that needs to improve by implementing the MHNIA as their decision-makers.

ACKNOWLEDGEMENTS

The authors would like to thank to Ministry of Higher Education of Malaysia for providing financial support under Fundamental Research Grant Scheme (FRGS) No. FRGS/1/2018/ICT02/UMP/02/7 (University Reference RDU 190178) and University Malaysia Pahang for laboratory facilities.

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