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RESEARCH ARTICLE

Comprehensive Evaluation of Publication and Citation Metrics for Quantifying Scholarly Influence

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ABSTRACT Ranking of researchers based on their scientific impact in a scientific community is indeed a very crucial task. However, identifying the researchers ranking helps the scientific community in various decisions such as awarding scholarships, selection for tenure, awarding achievements, giving promotions, etc. In literature numerous parameters have been proposed for the ranking of researchers, such as publication count, citation count, coauthor count, h-index, and its extensions. The current state-of-the-art research delineates that no such universally accepted parameter exists which can identify the most influential researchers. Therefore, it is necessary to determine an optimal parameter that can effectively rank authors. Furthermore, to identify the best parameter, few of the researchers conducted evaluative surveys as reflected in the literature. In these evaluative surveys, the researchers utilized a limited number of indices on the small and imbalanced datasets, followed by fictional cases and scenarios, this has made it challenging to ascertain the relative importance and impact of each parameter in comparison to the others. This research evaluates the h-index and its thirty-two variants, which are based on the number of publications and citation count category used for ranking the authors. We have collected data from 1050 researchers working in the mathematical domain for our experimental purposes. For the benchmark dataset, we have collected the awardees' data of the last two decades of four different societies belonging to mathematical domain. First and foremost, we have computed the correlations among the obtained values of the indices to assess their similarities and differences to evaluate indices. The result revealed that there is a high degree of correlation observed among h-index and it's twenty-four different variants. However, some indices showed a weak correlation, signifying that their rankings were highly dissimilar to those of other indices. Secondly, the position of awardees is checked in the top 10, top 50, and top 100 return records based on the ranking list of each index. The outcome of the last step divulges that A index, E index, H core citation, H2 lower index, K index, M index, and woginger index retrieved almost 80% of awardees in top 10% ranked list. Further, the analysis revealed that most of the winners (awards) were in the top tier, belonging to IMS, LMS, and AMS society returned by hg index, g index, k index, etc. indicating a relationship between the stated societies and the indices.

INDEX TERMS Author assessment parameters, citation count, h index, publication count, researcher ranking, variants of h index.

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I. INTRODUCTION

Currently, identifying influential researchers within a scientific community based on their research is a highly popular subject of discussion, but the measurement of scientific impact of a researcher is very crucial and tedious task [1]. However, the ranking of researchers assists the scientific community in taking various decisions such as, the selection of candidates for prestigious scientific awards, the selection of authors to review the papers, the distribution of scholarships and grants, the allocation of tenure positions, the identification of leading experts in a specific field [2], [3] etc. It can also assist students in the selection of a better and more relevant Ph.D. supervisor. Moreover, this can also be used by the government to categorize the institutions, funds, and project provided to ranked institutions whose research profiles are in the top positions [4], [5]. Furthermore, universities also used these ranking for the selection of their faculty. According to [6], the organization places its ranking position on its websites which influenced the institutional credibility. Moreover, students who want to continue their study abroad can also get help from this ranking and identify the best destination for themselves. It can also assist an employee to identify the best institution nationally and internationally for the employment purpose [7], [8].

To date, in literature, more than 70 parameters are proposed which are used to rank the authors [9]. According to [10] each parameter uses its own criteria to judge the authors. These parameters are either quantitative or qualitative based and some of them are hybrid in nature. Traditionally, researchers are ranked based on the number of publications [11], [12], citations count [13], [14] etc. However, it is commonly recognized that these metrics are insufficient in capturing the complete extent of a researcher's impact. For example, numerous researchers publish their work in conferences or journals with low-quality standards, which may not accurately reflect their research impact or significance also the high number of citations is not necessarily a reliable indicator of the quality, consistency, or longevity of a researcher's work. The number of citations can be influenced by a small number of highly praised review publications, which may not accurately reflect the researcher's overall contribution and impact. Additionally, it's crucial to understand that the practice of self-citation, where authors cite their work, as well as the phenomenon of critical citation, where authors cite a research paper as a means of critique, can impact the number of citations received by a research paper. To overcome these limitations h-index was introduced by [15] which measures the impact and productivity of an author's research output by combining the publication and citation count. This metric has become popular due to its simplicity, efficiency, and ability to capture both the productivity and impact of an author's research. Several restrictions of the h-index are also identified by the scientific community. For example, h index does not consider the number of citations received by an author's most highly cited publications. Another limitation of the h-index is that it does not take into account the collaborative nature of scientific research. To address these restrictions several new indices and variants of the h-index were also proposed such as the g index [16], t-index [17], AR index [18], e index [19], and P index [20] etc. Despite the availability of a huge number of ranking parameters for authors, the scientific community does not have a strong consensus on one of the parameters to rank researchers [21], [22] and there is ongoing research in this area [23], [24]. Previous studies have attempted to determine the significance of ranking parameters through hypothetical or imaginary case scenarios [25], [26]. While some of the studies have evaluated a different set of parameters on different domain datasets such as [21] and [27] evaluated citation intensity and publication age-based parameters on the civil engineering domain dataset, [28] and [29] recently evaluated parameters belonging from citation intensity-based indices and some of extensions of h-index, respectively on a field of mathematics dataset. Moreover, these studies have used a very limited no of parameters for evaluation with unbalanced dataset. Furthermore, no standard benchmark with a huge no of authors' records exists for evaluation. The actual behavior of each parameter can only be truly understood through empirical investigation using large and diverse datasets. Examining comprehensive datasets for analysis leads to a more comprehensive and accurate understanding of the strengths and limitations of each ranking parameter and guides the scientific community toward a better parameter for ranking researchers. The current state of the art in researcher ranking falls short of providing a comprehensive assessment of ranking parameters on a large scale.

To address this shortcoming, we present a study that perform the evaluation of the parameters available in the citation and publication count based categories [9], [30] on a large, diverse and balance dataset of authors that belongs to the domain of mathematics.

The selection of these parameters for evaluation was based on following reasons:

- In this category, the parameters are significantly higher compared to other categories.
- Additionally, the parameters in the other categories are also somehow dependent on the citation and publication count-based parameters.

The proposed study has a paramount concern, presenting the scientific community with best performing ranking indices that are both comprehensive and optimal. For evaluatory purposes, our study utilized a comprehensive dataset that included 525 awardees and an equal number of non-awardees, spinning around two decades from 1990 to 2023. This dataset included information about authors from the field of mathematics, allowing us to gain insights into trends and patterns over time. The central focus of the study is to investigate and determine the best indices to rank researchers. To achieve this goal, the study is designed to answer specific research questions deemed crucial in determining the most effective ranking measure.

RQ1.Which sort of correlation exists among the h-index and all its variants belonging to based on citation count and publication count?

RQ2. Which indices have the strongest influence in determining the presence of international award winners among the top-ranked authors?

RQ3. Which prestigious mathematical awarding societies for nomination of awardees have any association with h-index variants?

Awards-providing societies in the mathematical field are taken to be benchmarks to assess specified indices. The list of most prestigious mathematical societies are given below:

- International Mathematical Union (IMU)
- American Mathematical Society (AMS)
- London Mathematical Society (LMS)
- Norwegian Academy of Science (NASL)

The evaluation of several indices in this study represents a significant improvement over previous studies [31], [32], and [33] and will likely contribute to a greater understanding of the topic. It's important to note that this research does not aim to make predictions about awards, rather; it aims to examine the performance of each index. This research primarily focuses on identifying the most reliable and optimal indices.

The following sections of this paper are organized as follows: In the ''Literature Review,'' we present a brief summary of the ranking parameters. ''Methodology'' deals with the approach proposed by us for ranking the indices. In ''Evaluation and result,'' we have presented and discussed the findings of our study. Lastly, the ''Conclusion'' will provide the main findings implications and an overview of everything.

II. LITERATURE REVIEW

In recent decades, determining the scientific impact and influence of an individual or a group of researchers has become a crucial task. Knowing the scientific impact and influence of a researcher is often an essential requirement in various circumstances, such as hiring a new faculty member for a specific post, evaluating faculty members for promotions, assisting students in finding a suitable supervisor to oversee their PhD research, nomination of awardees in the scientific community, identification of peer reviewers for journals and conferences, and decisions regarding the continuation of research grants [34].

Several bibliometric indicators have been proposed for scientific assessments. It has been stated that the quantity of a researcher's work is measured by the number of publications they produce [26]. This metric does not accurately reflect the impact of the researchers. It merely represents the volume of research output [35]. According to [23] a researcher with many publications can be considered highly productive. However, relying solely on publication count to judge a researcher's performance is inadequate. This is due to the fact that numerous researchers publish their work in conferences or journals with low-quality standards, which may not effectively indicate the research impact or significance.

Moreover, it is worth noting that while a high number of citations can be seen as a sign of impact and recognition in the research community, it is not necessarily a reliable indicator of the quality, consistency, or longevity of a researcher's work. The citation count can be influenced by a small number of highly praised review publications, which may not accurately reflect a researcher's overall contribution and impact [36]. Additionally, it is crucial to understand that the practice of self-citation, where authors cite their work, and the phenomenon of critical citation, where authors cite a research paper as a means of critique, can impact the number of citations received by a research paper. These practices can artificially inflate the number of citations, creating a misleading perception of the impact and significance of research. Therefore, it is essential to consider a range of factors when evaluating the quality and impact of a researcher's work, rather than relying solely on the number of citations. In another study, [36] analyzed the citation counts of well-regarded scholars in the field of mathematics and its various subfields. Upon examination, they found that the variation in citation counts was not solely due to research quality or impact, but also to how the publications were internally cited or published. For instance, some subcategories of mathematics may receive a higher number of citations because of their strong connection to highly cited fields. They found that it is crucial to consider the method and context of citation analysis when evaluating the impact and significance of research rather than simply relying on the number of citations received.

Another parameter for ranking researchers is the co-author [37]. Authors who work together in a research study are referred to as co-authors. According to Liu and Cheng's 2005 study, an author with a vast network of co-authors is deemed to be the most influential. However, many research studies with individual authors do not indicate that they do not contribute to the scientific community.

To overcome these shortcomings, [38] proposed a technique known as the h-index to measure the scientific influence of researchers. Jorge Hirsch introduces several benefits of the h-index over the other bibliometric indices. The Hirsch index, commonly known as the h-index, evaluates a researcher's scientific output using a single numerical criterion. The scientific community has quickly adopted the newly proposed measure for research performance. The h-index revolutionized the field of bibliometrics: when the h-index was calculated for ten highly cited biomedical researchers, it was found that those with more citations also had a higher h-index. The introduction of the h-index has opened a new area of research.

Research [39] identified some limitations of the h-index. First, the h-index captures only an author's impact up to the calculation time and does not account for future citations. Second, the h-index may only be suitable for some disciplines, as the number of citations required to reach a high h-index can vary significantly. The h-index can also be biased towards authors who publish in high-impact journals or those with a larger number of publications. Additionally, the h-index can be inflated by excessive self-citations, leading to overestimation of an author's impact. Furthermore, the h-index does not consider recent authors' publications or the impact of their most recent work. Single-author papers can also pose a challenge to the h-index, and they may not accurately reflect the impact of interdisciplinary work, as authors may receive citations from a diverse range of disciplines and sources. To address these limitations of the h-index, several new indices and variants/extensions, commonly known as the g-index [40], ar-index [18], q2-index [25] and hg-index [25] etc. have been proposed by the scientific community. These modifications aimed to provide a more comprehensive and nuanced assessment of an author's research impact, overcome the deficiencies of the original h-index, and provide a more precise depiction of an author's research output.

In [15]calculated the correlation between the h-index and the h(2) index based on a dataset of 19 chemistry professors from Poland University. In 2008, Schreiber et al. systematically evaluated the g-index along with the h-index, a-index, and r-index using datasets from 26 physicists. Their findings indicated that the g-index is a more appropriate indicator than the h-index for assessing the overall impact of a scientist's publications.

In [41] assessed the h-index, complete-h, and g-index using a dataset obtained through various mathematical methods. The evaluation results demonstrated that the complete h-index outperformed the g-index and h-index. In [21] evaluated the h-index and its various derivatives based on citation intensity and publication age using a large dataset from the civil engineering domain. Furthermore, in, [33] evaluated the h-index and its variants based on quantitative and qualitative indices using a comprehensive dataset from the field of neuroscience.

Recently, [28] and [34] conducted a systematic evaluation of citation intensity-based h-index indices on a dataset within the domain of mathematics. The main purpose f the evaluation was to identify the best-performing indices and distinguish mathematicians who had won awards. These studies employed a parsimonious approach by utilizing a limited number of parameters to validate their results. However, it is important to note that using a reduced number of parameters to validate findings may not necessarily lead to a more comprehensive understanding of the underlying phenomenon. Another researcher [31] utilized a machine learning algorithm for ranking indices to find the most influential index from 16 indices using logistic regression. For experimental purposes, they utilized the Civil Engineering domain dataset, which contained 500 researcher records. They reported that the author/paper parameters outperformed all the other parameters. Recently, [42] proposed some rules using the top five highest-performing indices against different fields (Civil, Mathematics, and Neuroscience). They collected data from 500 researchers from each department. They reported that their rules retrieved 70% of the awardees in the top 100 results. To the best of our knowledge, no study has used a significant number of parameters to validate their findings.

Despite the availability of various ranking parameters, there is no universally agreed upon method for ranking researchers in the scientific community. Prior research has aimed to establish the importance of ranking parameters by conducting analyses using hypothetical case scenarios. However, we contend that a complete understanding of each parameter's behavior can only be achieved by using extensive and varied datasets. In the future, we will analyze these indices on other domain datasets such as Computer Science, Civil Engineering, Electrical Engineering and Neuroscience.

III. METHODOLOGY

Figure 1 illustrates the architecture diagram of our proposed methodology. Our approach evaluates the publication and citation count-based parameters to determine the most effective indices for ranking researcher's mathematics domain. The main aim of this research is to accurately and meaningfully recognize and reward the contributions of these researchers.

A. DOMAIN SELECTION

For the purpose of this research, we opted mathematics field to evaluate h-index and its thirty-two variants. The primary reason for selecting mathematics as the field for evaluating the h-index and its variants in this study is its interdisciplinary connections: it prevails with other branches of science, such as physics, computer science, and chemistry. According to [25]. it is crucial to evaluate ranking parameters in various fields, as this can contribute to promoting academic growth and development. By conducting evaluations across multiple areas, we can gain a more comprehensive understanding of the effectiveness of ranking parameters and their impact on different fields, which in turn can help identify opportunities for improvement. This facilitates the advancement of research in various disciplines.

B. TAXONOMY BUILDING

One way of categorizing the various branches of Mathematics is through MSC, the Mathematics Subject Classification System. The latest version of this classification system, known as MSC2020, contains 64 top-level categories, where 40 categories are purely mathematical and 24 belong to Applied Mathematics. The system under consideration is extensively used in major mathematics journals, including the Journal of the American Mathematical Society, Mathematics of Computation, and Conformal Geometry and Dynamics. to categorize and organize research articles into specific mathematical fields. However, we collected the research articles of the researchers based on the categories implying the mathematical domain.

C. DATASET COLLECTION IN MATHEMATICS

We collected a large and diverse dataset to evaluate the proposed methodology. The dataset contains data records from 1050 record proportions, utilizing 525 non-awardees and 525 awardees' data. The proportion of non-awardees' data in

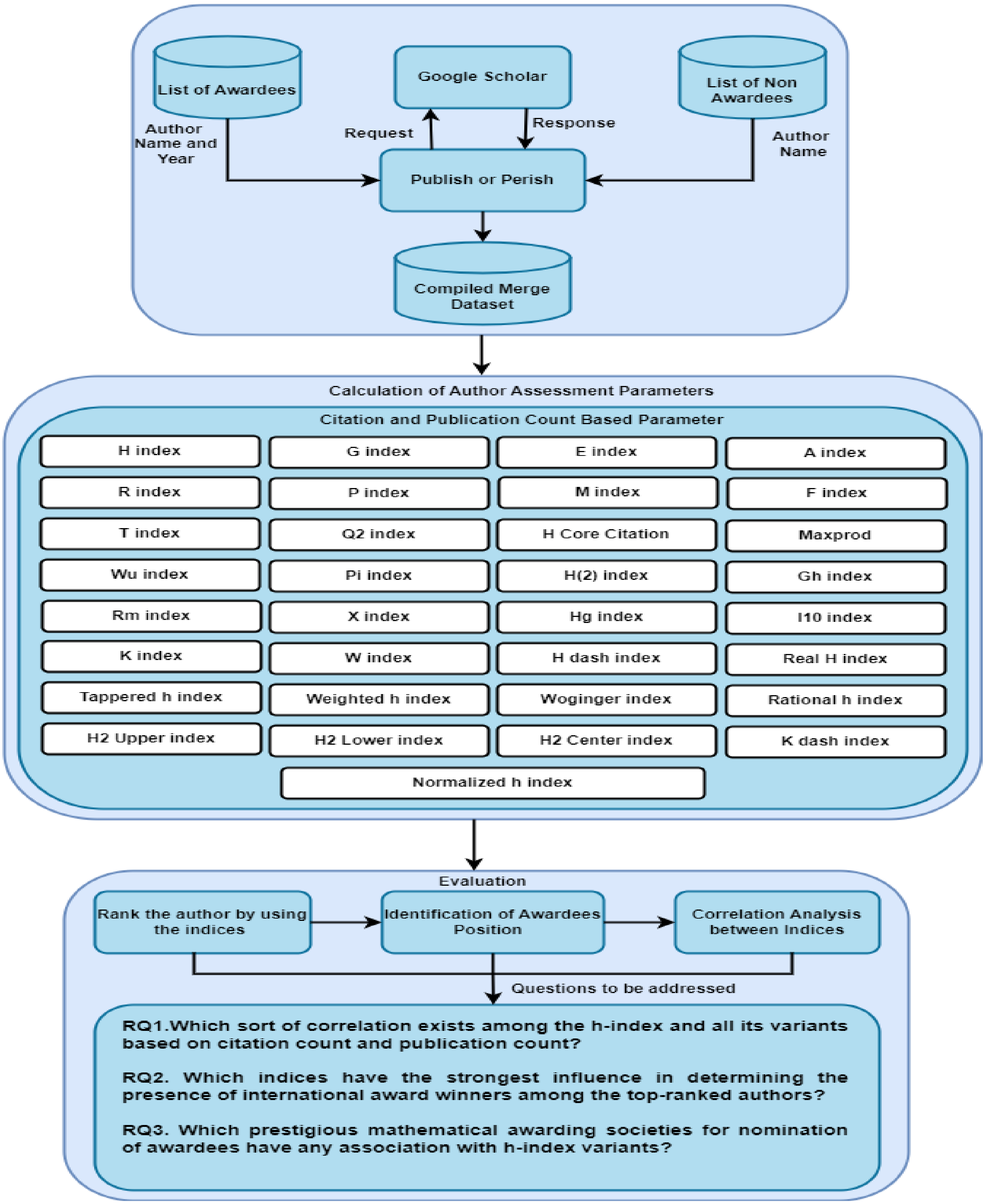

FIGURE 1. Illustration of the proposed methodology.

the dataset was taken from the dataset used by [28] and [34]. As in the dataset of [28] and [34] it contained awardees constructing it to in a very limited number of let's say it had entries until 2013. We updated the awardees and collected data again by visiting different societies websites and collected names and years for researchers over the last two

TABLE 1. Year wise awardees count.

Year	No of Awardees	Year	No of Awardees
1990	11	2007	16
1991	15	2008	18
1992	6	2009	24
1993	10	2010	22
1994	19	2011	18
1995	10	2012	22
1996	11	2013	15
1997	11	2014	33
1998	14	2015	12
1999	14	2016	12
2000	17	2017	16
2001	14	2018	23
2002	21	2019	12
2003	23	2020	13
2004	16	2021	20
2005	15	2022	20
2006	29	2023	13

decades. Table 1 presents the number of year-wise awards. To extract the awardee's data by name, we have used the publish or perish platform. Using the hold-on strategy, we collected the researcher's records even before the award-receiving year. The publish or perish software employs a sophisticated algorithm to extract both primary data, while accompanying the metadata of the authors from Google Scholar. Google Scholar was selected as an extraction tool because of several factors that not only include its wide coverage of academic publications across various disciplines. However, it is accessible to researchers worldwide and has the ability to retrieve both open-access and pay-walled publications. Numerous research studies have compared the coverage of google scholar with Web of Science and discovered that the latter experienced a growth rate that was 13% higher than WoS. Furthermore, Google Scholar's citations have risen by an average of 1.5% each month in the previous year. Moreover, Google Scholar is a dynamic and constantly updated platform in which new data are uploaded weekly, ensuring that the information it provides is always up-to-date and relevant [43]. Publish or perish used google scholar to extract the data. Further, this method uses the input following the format of the author name and the award year, hence returning the author's metadata (Publication Year, Authors Information). To set the dataset to be fair, we collected the non-awardees data in the same amount referring to each year against the number of awardees for that specific year. For example, in 1990, the total number of awardees was 11; therefore, we collected data from 11 non-awardees before 1990. We applied the same techniques as for the others. The statistics for our dataset are presented in the following Table 2.

D. DATA PREPROCESSING

Data collected from sources such as Google Scholar must be thoroughly cleansed before use for any analysis or evaluation. The purpose is to emit irrelevant or incorrect information, known as noise, presented on such sites, which can negatively impact the validity of the results. The data-cleaning process involves identifying and removing this noise and can include steps such as verifying the accuracy of the data and eliminating duplicate entries. This extensive collection of research materials was subjected to two critical processes to improve their quality and relevance. First, to assess the consistency of each publication within the mathematical field, a filter was applied to eliminate irrelevant or non-mathematical content. Subsequently, the author's disambiguation process was carried out. To identify and eliminate duplicate entries caused by authors publishing under different names. After verifying the mentioned steps, the characteristics and properties of the final data set for evaluation and the results are noted, which is depicted in Table 3.

TABLE 2. Dataset statistics before preprocessing.

Features	Total Count
No of Authors	1050
No of Awardees	525
No of Non Awardees	525
No of total Citation	14,370,007
No of total Publication	204,896

TABLE 3. Dataset statistics after preprocessing.

Features	Total Count
No of Authors	1050
No of Awardees	525
No of Non Awardees	525
No of total Citation	14,369,007
No of total Publication	204,796

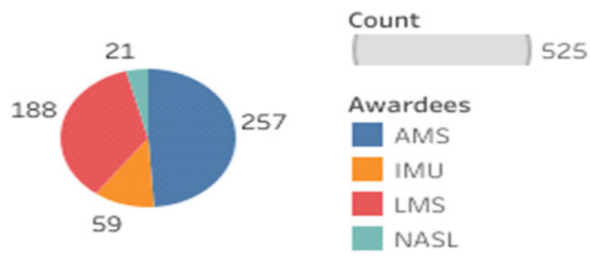

FIGURE 2. Percentage of awardees relative to society.

E. BENCHMARK DATA SET

To thoroughly evaluate the various ranking metrics in the current study, lists of awards were extracted from several mathematical society-presented awards. The list contains 30 internationally prestigious awards. These awards are widely recognized in the mathematical community and are often considered significant accomplishments for mathematicians and researchers. These 30 international prestigious awards are presented by several renowned mathematical societies and organizations, including the LMS, IMU, NASL and AMS. These organizations are dedicated to promoting and advancing mathematics and supporting the research and academic endeavors of mathematicians (across the world) [28], [41] and [34] considered awards from these societies to be the benchmark. One of the main reasons that researchers

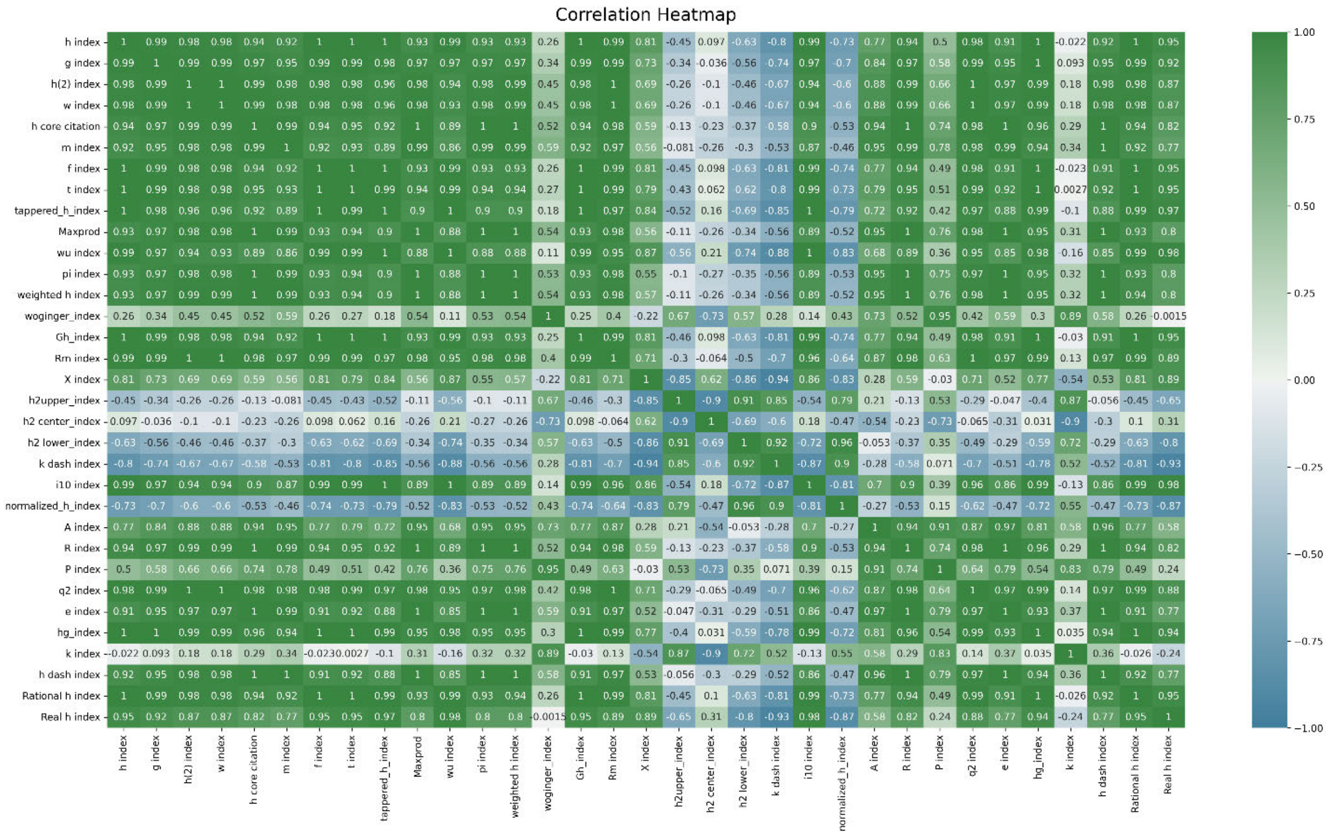

FIGURE 3. Correlation of indices.

intend to consider these societies and their awardees is that there is no other optional benchmark available for evaluating such indices. The below Figure 2 represents the number of awardees with respect to each society.

F. CALCULATION OF INDICES

Following the data collection and preprocessing stage, the research proceeded to calculate thirty-three indices based on the collected data. The indices are presented in Appendix A along with their corresponding calculations. Once all the indices were calculated, we generated separate ranking lists for each index. Consequently, thirty-three distinct ranking lists (of the authors) were obtained. These lists were further analyzed to address the three research questions at hand.

IV. EVALUATION AND RESULTS

In this section, we discuss the findings and results.

A. RQ1: CORRELATION OF COMPUTED INDICES

The primary objective of correlating these ranked lists was to analyze the underlying relationship and the extent of similarities between them. Utilizing the Spearman correlation coefficient, we calculated the correlation among the ranked lists. The mathematical computation for the Spearman correlation coefficient is given in Equation 1.

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} \tag{1}$$

The correlation coefficient, represented by ‘rs’ in the equation, is a metric that gauges the direction and strength of the linear relationship between two variables. Its value ranges from -1 to +1, with -1 indicating a perfectly negative correlation, +1 indicating a perfectly positive correlation, and 0 indicating no correlation between the variables. A high correlation coefficient between the two ranking indices indicates a strong linear relationship between them. Specifically, this suggests that these two lists exhibit similar ranking patterns and even tend to rank researchers similarly. As shown in Figure 3, the correlation coefficients between the ranked lists were calculated. Generally, when the absolute value of the correlation coefficient is between 0.00 and 0.25, it is interpreted as a weak linear relationship between the two variables. A correlation coefficient of 0.50 is typically interpreted as indicating a moderate linear relationship between two variables. Similarly, a correlation coefficient falling within the range of 0.75 to 1.00 is generally considered to indicate a strong linear relationship between the variables. Strong values are presented, specifically using the green color scheme. Whereas the weak values are represented by a lighter shade of green. Sky-blue is used to present the negative values

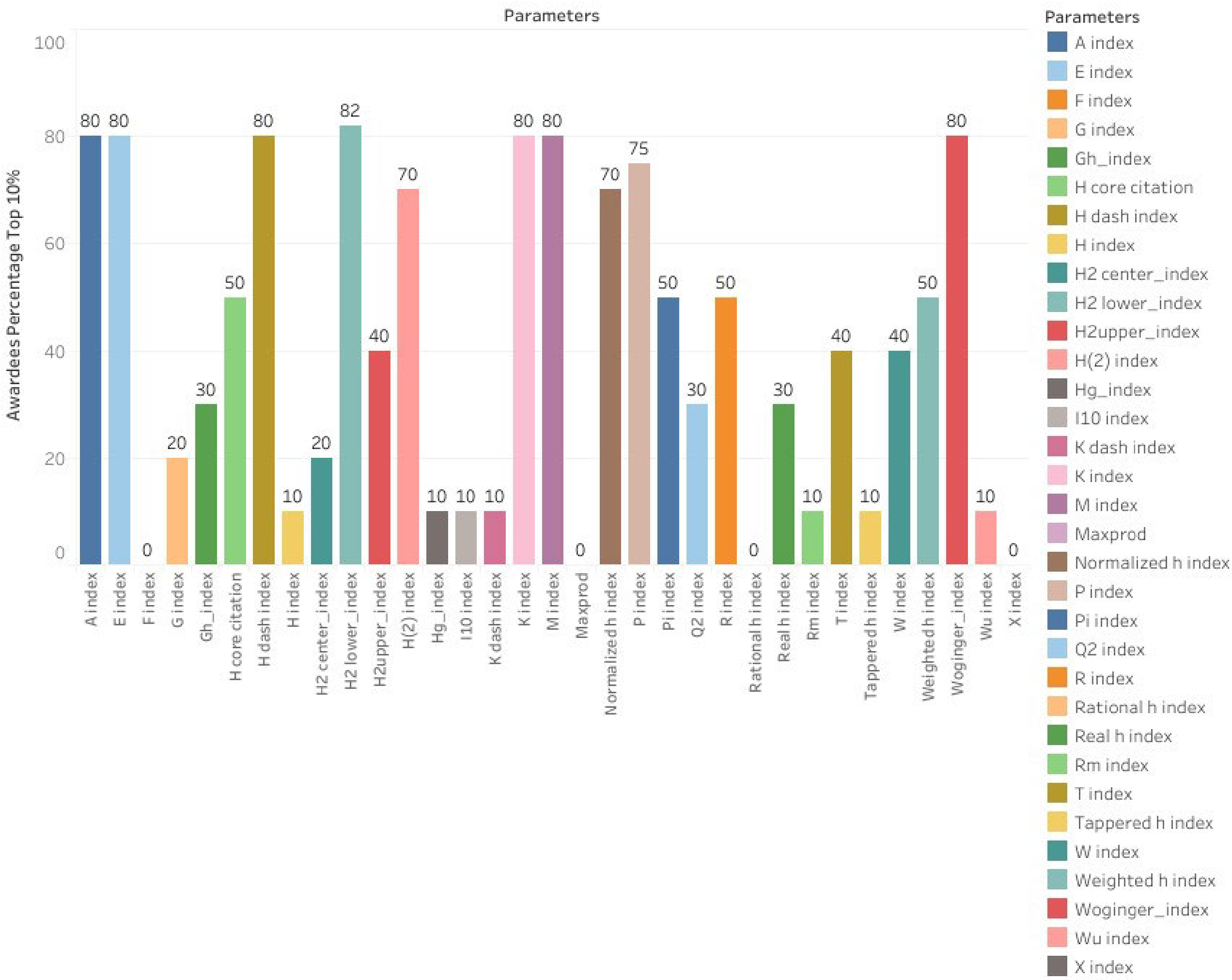

FIGURE 4. **Awardees percentage in the top 10% of ranked list.**

and present negative correlation. The correlation coefficient of a variable with itself is always 1, since a variable perfectly correlates with itself. And, in general, the correlation coefficient can range from -1 to +1, where a value of -1 indicates a perfect negative correlation, a value of +1 indicates a perfect positive correlation, and a value of 0 indicates no correlation. In the context of comparing multiple variables, a strong correlation between two variables indicates that they are highly related and tend to move together, while a weak correlation indicates that they are less related and may not move together as closely. Weak correlation coefficients detected for some indices in the dataset indicate their rankings are notably different from other indices, which may have important implications for the analysis and interpretation of the results The results of our initial research question have motivated us to investigate the subsequent questions.

B. RQ2: TREND OF AWARDEES IN THE RANKED LISTS

We conducted an analysis to determine the impact of the indices in ranking awardees at the top of the list. To accomplish this, we needed to check the prevalence of awardees within the top 10%, 50%, and 100% of the ranked list for each parameter. Once the data was gathered, we evaluated the authors' rankings for each index individually. We then located and noted the positions of the award winners within the ranked lists. Furthermore, we calculated the number of award winners who ranked within the top 10%, 50%, and 100% of each list. Based on the analysis shown in Figure 4, it can be observed that among the award winners who rank within the top 10% of authors, the A-index, E-index, H-dash index, h2 lower index, K-index, M-index, and Woginger index have the highest occurrence, reaching up to 80%. The P-index, M-index, and H2upper-index also demonstrate an average performance by returning awardees in between 40 to 80 percent. Referring to figure 5, the k index has the highest occurrence of up to 80% among the award winners, primarily within the top 50% of authors. The lowest performance was observed for the X-index and I10-index. Based on the data presented in Figure 6, it can be observed that the X index has a relatively high occurrence rate of up to

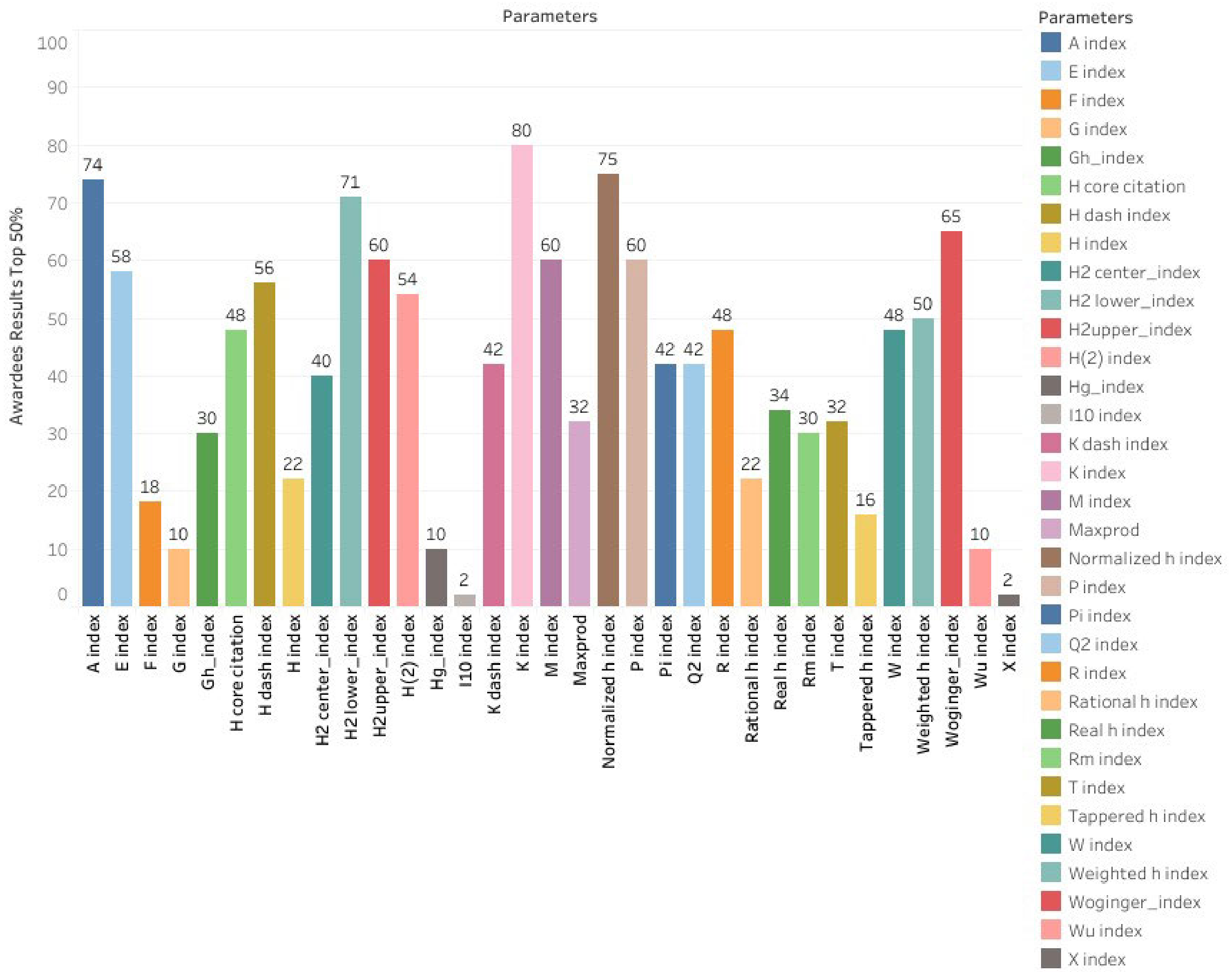

FIGURE 5. **Awardees percentage in the top 50% of ranked list.**

20% among the award winners in the top-ranked list, which is 100%. However, when it comes to considering the ratios following in the category of the top 100% ranked list, X index exhibited comparatively poor performance, indicating that it is not advisable to utilize this index for assessing the impact of authors or ranking them accordingly.

C. RQ3: WHICH PRESTIGIOUS MATHEMATICAL AWARDING SOCIETIES FOR NOMINATION OF AWARDEES HAVE ANY ASSOCIATION WITH H-INDEX VARIANTS?

In this section, we focus on the evaluation of the third research question, which involves determining the impact of these indices on the awarding society. To investigate this question, we analyzed the occurrence of award winners in the top 10%, 50%, and 100% of the ranked list. Our dataset consisted of 525 awardees and an equal number of 525 non-awardees as the benchmark. To ensure impartiality and eliminate any bias, an equal number of award winners and non-awardees were taken as a sample for the study. Among these, 525 awardees were identified, with 257 affiliated with AMS 59, IMU 188, LMS, and 21 from NASL, as depicted in figure. Traditionally, it is believed that award recipients have a well-established research background. Citations and publications serve as a piece of evidence in such situations. Such assumptions have led many to expect that all awardees should rank among the top 10% (of authors) when sorted by these indices. However, the current analysis has shown that this assumption is not always valid, and there have been cases in which some recipients (awards) do not meet these expectations. Figure 7, 8, and 9 represent the results of the indices against societies.

Upon examining the influence of the h-index extensions on awarding societies, the following observations were made:

AMS

- In the top 10% of the results (Presented in Figure 7), the Pi index and k dash index outperformed all other

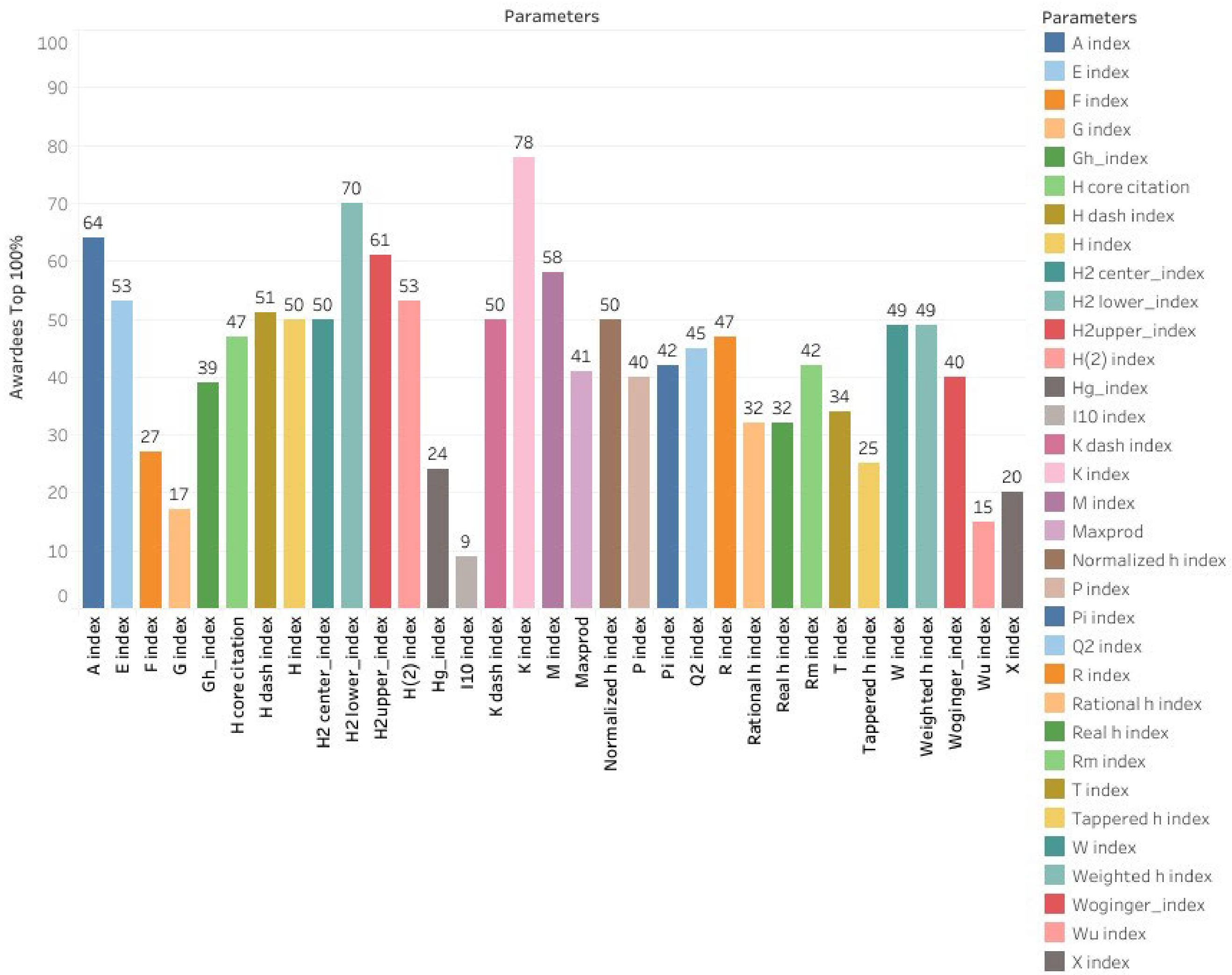

FIGURE 6. **Awardees percentage in the top 100% of ranked list.**

indices by retrieving 100% of the awardees in the ranked list. Moreover, the G index, M index, T index, Woginger index, and H2 upper index showing average performance succeeded in retrieving 50% awardees. Furthermore, the H core citation index, Tappered h index, Weighted h index, A index, R index, and P index show low performance by retrieving 15% of awardees, and the remaining indices return nothing.

- In the top 50% of the results (Presented in Figure 8), the G, Wu, and Hg indices outperformed all other indices by retrieving almost 80% of the awardees. Moreover, the h-index, f-index, H2 upper, and rational h-index showed average performance retrieved up to 55% of awardees. Furthermore, the W index, H core citation, Maxpord, H2 lower, and E index exhibited almost the same performance, retrieving 35%. The k-dash index showed poor performance with a retrieval rate of 9%. Notably, none of the award winners was identified by either the H10 or X index.
- In the top 100% results (Presented in Figure 9), the G index and I10 index remained good, that is, 75%. The X index, H2upper index, and K index show equal performance i.e., 50%. The performance of the H index, W index, H core citation, M index, F index, T index, Tappered h index, Maxprod, Wu index, Pi index, Woginger index, Rm index, A index, P index, Q2 index, and Real h index remains up to 45%.

IMU

- In the top 10% percent result (Presented in Figure 7), the Rm, I10, and Hg indices resulted in the maximum number of awardees from IMU society and exhibited a performance level of 100%. The performance of the W index is good (75%). The G and Tappered h indices showed a performance of up to 55%. The Weighted h-index, A-index, P-index, and H-dash index remained up to 40%. The H(2), M, Tappered h, A, and P indices show poor performance of up to 15%, while the remaining indices return no awardees.

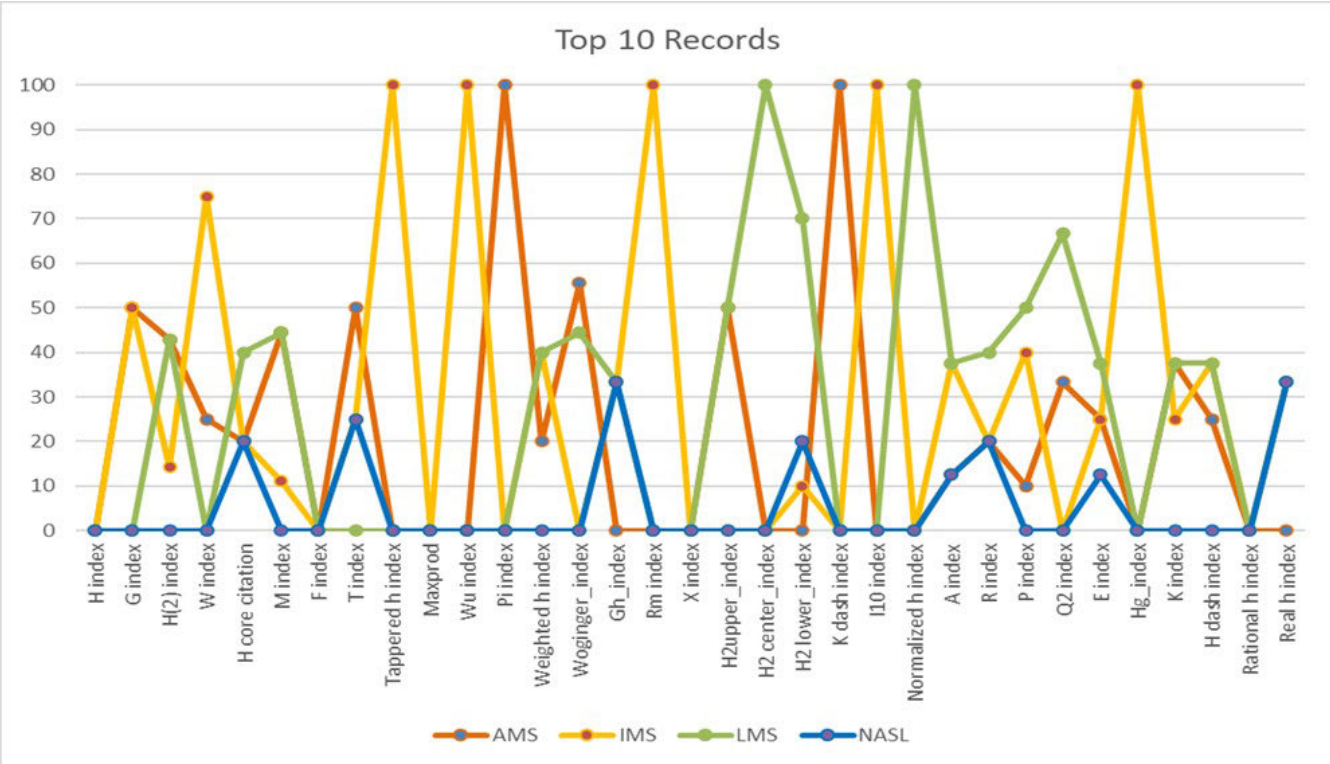

FIGURE 7. Awardees percentage in the top 10% of ranked list.

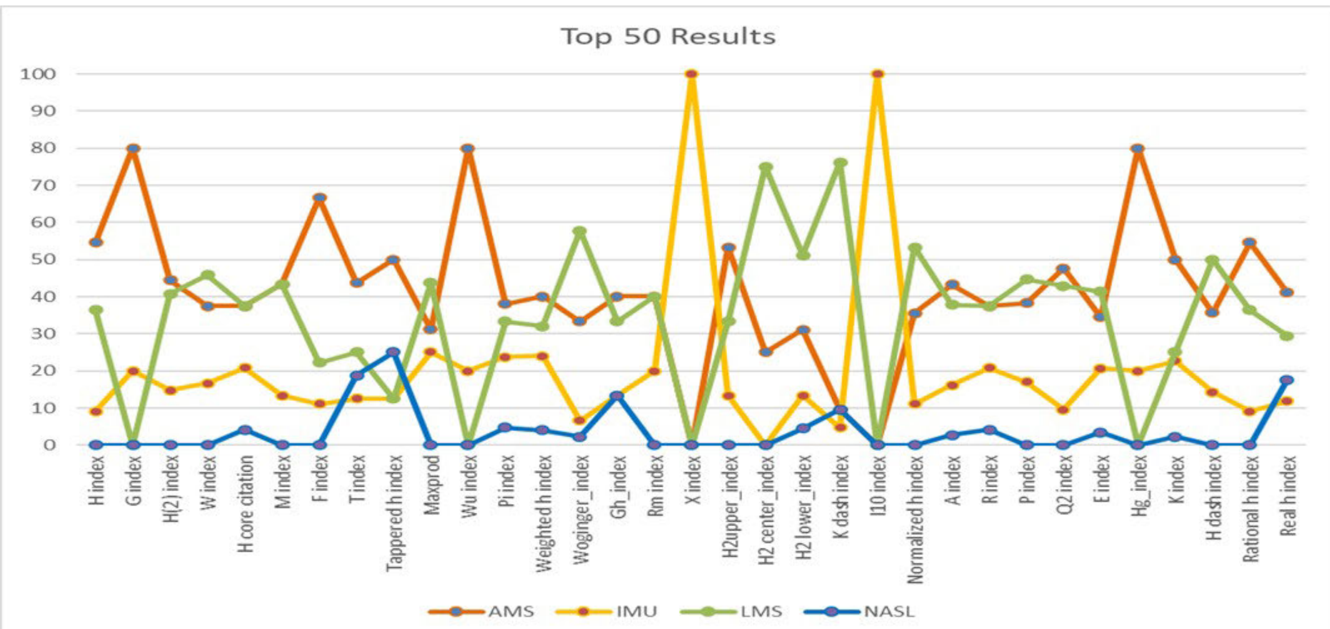

FIGURE 8. Awardees percentage in the top 50% of ranked list.

- In the top 50% of the results (Presented in Figure 8), the X and I10 indices outperformed all other indices by retrieving 100% awareness. The performances of the G index, H core citation, Pi index, weighted h index, Rm index, R index, E index, and K index remained up to 24%. The H, F, T, K dash, Q2, and rational h indices showed poor performance up to 13%, while the remaining indices returned no results.

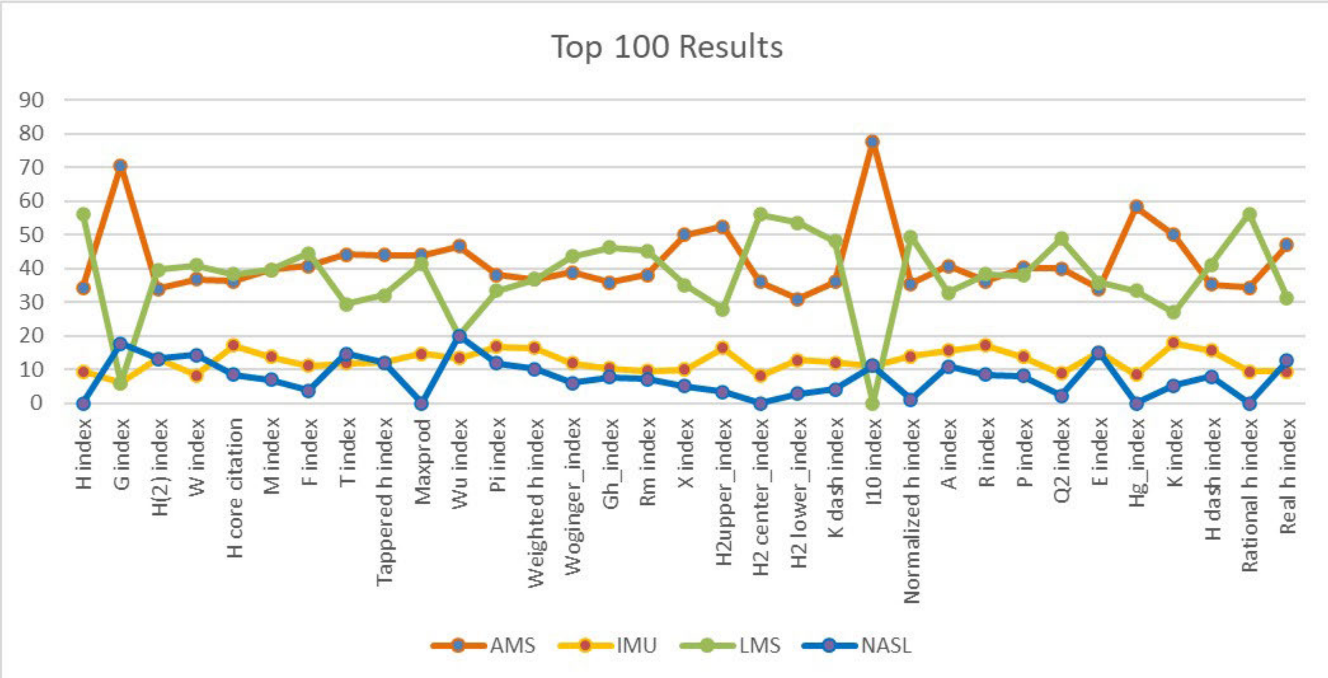

FIGURE 9. Awardees percentage in the top 100% of ranked list.

- In the top 100% of results (Presented in Figure 9), the Pi index, weighted h index, H2upper index, R index, K index, and H dash index remained up to 17%. The H, W, Rm, H2 center, Q2, Hg, and real h indices demonstrate a performance level below 10

LMS

- In the top 10% of results (Presented in Figure 7), the H2 center index and normalized h index exhibit a performance level of 100% from the LMS society. The performances of the Q2 index and H2 lower index were good (70%). The H2upper and P indices exhibit the same performance level of up to 50%. However, the remaining indices yielded no results.
- In the top 50% of the results (Presented in Figure 8), the K dash index and H2 center index remained good at 76%. Whereas the performance of The Woginger index and the H2 lower index showed a performance level of up to 55%. Moreover, the H(2), Gh, H2upper, A, and R indices demonstrated a performance level below 40%. However, the remaining ones returned no results.
- In the top 100% of results (Presented in Figure 9), the H index and H2 lower index retrieved up to 56% awardees, whereas the performance of the normalized h index, Q2 index, Gh index, Rm index, K dash index, and H dash index demonstrated a performance level of up to 44%. Moreover, the G index shows poor performance (up to 5 %), and the remaining index returns no results.

NASL

- In the top 10% of results (Presented in Figure 7), the real h index and Gh index remain the same (33%). However, the H core citation, T index, H2 lower index, and R index demonstrated performance levels below 40%. Moreover, the A index, E index exhibit a performance level of below 12% and the remaining one returns with no result.
- In the top 50% of the results (Presented in Figure 8), the Real h index and T index retrieved awardees of up to 18%, whereas the K dash index, Gh, was up to 13%. Moreover, H core citation, Pi index, Weighted h index, Woginger index, H2 lower index, A index, R index, E index, and K index demonstrate a performance below 4% while the remaining one return no awardees.
- In the top 100% results (Presented in Figure 9), the Wu index outperformed all other indices retrieved up to 20%. The G index, H(2) index, W index, T index, and E index were up to 17%, whereas the H core citation, M index, F index, Woginger index, Gh index, Rm index, X index, H2upper index, K dash index, normalized h index, R index, P index, Q2 index, K index, and H dash index demonstrated performance below 10%. Remaining retruns with no results.

From the comprehensive analysis, we identified that some of the indices are more suited than others. For example, the G index is more suited to AMS than to other societies because it is outperformed in all types of ranked lists. Similarly, the I10 index is suited to the IMU, the H2 center index to the LMS, and the Real h index to the NASL society. Furthermore, this analysis provides valuable insights into the strengths and weaknesses of different societies and their approaches to selecting and recognizing outstanding individuals in their respective fields. By identifying the awarding societies that

TABLE 4. Indices and its calculation.

Name of Index	Calculation Formula
H-index	h = max (numbers of articles with >= h citations)
G-index	A set of papers has a g-index g if g is the highest rank such that the top g papers have, together, at least g2 citations.
Hg-index	hg =$hg = \sqrt{h * g}$
A-index	A-index=$A = \frac{1}{h}\sum_{p=1}^{h} cit_p$
R-index	R-index=$\sqrt{\sum_{p=1}^{h} Cit_p}$
P-index	P-index =$(\frac{C^2}{p})^{\frac{1}{3}}$
Q^2-index	Q^2=$\sqrt{h * m}$
K-index	K-index=$\frac{\frac{C}{P}}{\frac{C(h-tail)}{C(h-core)}}$
E-index	e-index=$\sum_{p=1}^{h} Cit_p - h^2$
f-index	$\binom{max}{f}\frac{1}{\frac{1}{f}\sum_{p=1}^{f}\frac{1}{Cit_p}} \geq f$
T-index	$\binom{max}{t} exp\left[\frac{1}{t}\sum_{k=1}^{t} ln(Cit_k)\right] \geq t$
Tappered h-index	$H_{T(j)} = \frac{n_j}{2_j-1}, n_j \leq j \quad and \quad h_{T(j)} = \frac{j}{2_j-1} + \sum_{i=j+1}^{n_j}\frac{1}{2_j-1}, n_j j$
Wu index	The w-index of an author is calculate, as if at least w of their articles have garnered 10w citations, while the remaining publications have received less than 10(w+1) citations each.
Weighted h-index	$R_w(k) = \frac{\sum_{p=1}^{k} Cit_p}{h} \quad h_w = \sqrt{\sum_{k=1}^{R} Cit_k}$
h(2)-index	The h(2)-index is the maximum whole number such that the h(2) most cited articles by a scholar have each received at least (h(2))2 citations.
Woeginger index	$w = \binom{max}{w}(Cit_p \geq w - p + 1) \quad for\ all\ \ p \leq w$
Rm-index	$R_m = \sqrt{\sum_{k=1}^{h} \mathrm{Cit}_k^{\frac{1}{2}}}$
m-index	A m-index is calculated as the median number of citations received by the h-core articles.
X-index	$x = \sqrt{\binom{max}{k} kCit_k}$
h2 upper-index	$h^2upper = \frac{\sum_{k=1}^{h}(Cit_k - h)}{\sum_{k=1}^{m} Cit_k} * 100 = \frac{e^2}{\sum_{k=1}^{m} Cit_k} * 100$
h2 center-index	$h^2center = \frac{h*h}{\sum_{k=1}^{m} Cit_k} * 100$
h2 lower-index	$h^2lower = \frac{\sum_{k=h+1}^{m}(Cit_k - h)}{\sum_{k=1}^{m} Cit_k} * 100$
h` –index (h dash)	$h' = Rh = \frac{eh}{t}$
Rational h-index	$h_{rat} = h + 1 - \frac{k}{2h+1}$
I10 index	This is a simple and direct measure of indexing that involves counting the total number of papers published by a journal that have received at least 10 citations.
Normalized h-index	$normalized\ h - index = \frac{h}{pub_{count}}$
Pi index	$\Pi\ index = 0.01C(P\Pi)$
Gh-index	$Gh^a = \sum_{p=1}^{m} sing(Cit(\mathrm{pub}_b^a) - GH) \quad where\ \ sing(x) = 1, x \geq 0\ and\ \ 0, x \leq 0$
W index	Scholars' w-index is defined as w, which represents the number of their top articles that have at least 10w citations each. While w-index can be a useful measure for finding impact of scholar, it may penalize young scholars who have recently started working or those who have not yet published enough papers.
Maxprod	The maximum value of i * ci can be found by examining the publication rank of an author, where ci represents the number of citations for the ith most frequently cited paper among all the citations.
H core citation	The h-core citation index takes into account only those publications that have been cited at least h times and ignores those that have not achieved this threshold
K dash index	$k' = \frac{Cit_{all} - Pub_{Count}}{Cit_T - Cit_H}$

are most effective at leveraging indices, researchers and analysts can develop a more targeted and efficient strategy for predicting and honoring awardees. Moreover, this analysis can help inform and ensure future improvements when it comes to handling awards and identifying deservers. This can be done by highlighting areas that require additional attention, accompanied by resources used to point out the most deserving individuals or individuals, hence recognizing them for their contributions.

V. CONCLUSION

This research has conducted a comprehensive analysis of parameters used to evaluate authors by utilizing the h-index and its 32 variants. These variants are based on categories such as publication and citation count, which are important metrics in determining an author's impact and productivity in their field of study. A comprehensive dataset is used that covered a period of two decades, from 1990 to 2023 and it comprises 525 non-awardee authors and 525 awardee authors from prestigious scientific societies in the field of mathematics. Upon analyzing the data, we have uncovered several noteworthy and thought-provoking trends that warrant further discussion. These trends, which are significant in their scope and impact, shed new light on the topic under investigation and provide important insights for future research.

In the initial stage of experimentation, we calculated the correlations among the computed values of the indices to evaluate their similarities and differences. After conducting our analysis, we found that many of the indices were highly correlated, indicating that their rankings their rankings are largely congruent. However, we also observed certain indices with weak correlations, which suggests that their rankings diverge from those of other indices. This finding underscores the importance of carefully selecting appropriate metrics for evaluating author productivity and impact, as different indices may yield distinct results.

We conducted an analysis of the distribution of awardees within different percentile ranges (top 10%, top 50%, and top 100%) based on their corresponding index rankings. This examination offers valuable insights into the relative performance of awardees across various indices and provides a comprehensive assessment of their productivity and impact. By examining the distribution of awardees within these percentile ranges, we can identify any patterns or trends that may be indicative of the effectiveness of different indices in measuring author performance.

Following this, we employed data from international awardees associated with four esteemed Mathematics societies, namely, the AMS, IMU, LMS and NASL to serve as a benchmark in assessing the effectiveness of the indices. We performed an analysis of the degree of reliance of these societies on the indices to evaluate their potential in accurately assessing author productivity and impact. Thus, while the number of citations and publications are commonly used as indicators of research excellence, it is important to recognize that they may not be the sole determinants of an individual's eligibility for awards or recognition. A more comprehensive and holistic approach that considers a broader range of factors may be necessary to better capture the diverse talents and contributions of researchers and scholars.

VI. FUTURE WORK

Apart from these types of indices, researchers and ranking communities have proposed various other indices that belong to the publication age-based and author count-based categories. It is essential to test these indices on comprehensive datasets from mathematical and other domains to evaluate their effectiveness.

APPENDIX A

See Table 4.

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