

# Software Engineering in Saudi Arabia: A Bibliometric Assessment

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**ABSTRACT** This paper presents a bibliometric assessment of the Software Engineering (SE) community in the Kingdom of Saudi Arabia (KSA). The assessment was based on the number of SE papers published by KSA-based SE researchers in SE-related venues and indexed in Scopus between years 1984–2019. The assessment aimed to measure the volume of research contribution produced by KSA-based researchers and institutions to the SE field. 802 SE papers were published by KSA-based SE researchers and the top active institution in the domain is King Fahd University of Petroleum and Minerals (KFUPM) and the top active researcher is Mohammad Alshayeb who is affiliated to KFUPM. The results estimated that KSA produced around %0.62 of the world-wide SE knowledge which indicates that KSA SE community needs to increase the volume of its publications to be more active in the worldwide SE community. The results also show that from 2007 onwards, the annual publication trend of KSA SE community has been growing in a healthy rate reaching 113 published papers in 2019. Additionally, 56% of the papers were internationally-authored and the highest international collaborations were with researchers from the USA, Tunisia and the UK respectively. In general, KSA is performing well comparing to three of its neighboring countries (UAE, Jordan and Egypt) in terms of the quantity of the published SE papers and received citations. However, in comparison to developed countries, the results suggest that more work on the quantity, quality and visibility of the SE papers authored by KSA-based researchers is needed.

**INDEX TERMS** Bibliometric analysis, software engineering, Saudi Arabia.

## I. INTRODUCTION

The discipline of Software Engineering (SE) has been in existence for over fifty years. The term software engineering was first introduced in the 1968 NATO Software Engineering Conference [1]. The term was intended to stimulate thoughts and discussion on the encountered software crisis at the time.

Software Engineering has been significantly influencing almost every other discipline as all modern societies nowadays heavily relies on the usage of software technology. Over the past five decades, the research contributions to the domain of SE has been substantially growing in depth and breadth. This paper aims to assess the current Saudi SE community research state by conducting a bibliometric analysis of its SE research data.

Given the evident importance of the SE discipline, it is important to question and assess the various aspects of SE, for instance: (1) Who are the active scholars/researchers in the field?, (2) What are the active institutions (or research

centres) in the field?, (3) What are the highly adopted re-search methodologies in the field?, (4) Which trendy re-search topics are in the field?, (5) What are the countries that highly contribute to the field?, and (6) What is the progress in the quantity of SE publications in comparison to other disciplines of engineering and science?

Enlightened by the previously mentioned questions, several bibliometric studies in the field of SE have managed to address some of those questions such as [2]–[21]. For example, [9], [10], [12], [13], [15], [18]–[21] addressed questions (1) and (2) by ranking the top researchers/scholars and institutions in the field of SE worldwide from 1996 to 2008 and from 2010 to 2017 respectively. Additionally, [11] and [2] aimed to address questions (3) and (4) respectively. Other bibliometric studies were performed on a country-wise level to rank the top researchers/scholars and institutions in the field of SE (e.g., in Canada [5] and in Turkey [7]).

Nevertheless, to the author's best knowledge, there has not been a bibliometric study performed specifically in the context of the Saudi SE community. Inspired by the work done by Garousi (2015), this paper reports on a bibliometric

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study that aims to assess the current state of SE research in the Kingdom of Saudi Arabia (KSA). The ultimate goal of this study is to help the SE Saudi researchers and PhD students to wisely choose their research paths and increase the KSA SE community's awareness of their current strengths, weaknesses and opportunities. To reach this aim, the author collects and analyses bibliometric data from a widely used and well-known online research articles database, Scopus. The results provided in this paper can be useful to SE researchers, research funding bodies and research policy and decision makers inside or outside KSA.

The rest of this paper is organized as follows. In section 2, the related studies are presented and discussed where-as section 3 discusses the adopted research methodology. Section 4 represents and discuss the findings of this study and then the conclusion and future work are presented in Section 5.

## II. RELATED STUDIES

Bibliometric ranking studies are common in the field of SE, e.g., [2], [3], [5]–[23]. Glass *et al.* [9], [10], [12], [13], [18]–[21] conducted one of the most popular annual SE bibliometric studies that ranked top SE researchers and institution worldwide from 1996 to 2008. They based their ranking on the number of published SE papers weighted scores. The researchers covered the papers appeared in six chosen journals and one magazine that have the highest impact factors of all SE journals.

However, Glass *et al.* [9], [10], [12], [13], [18]–[21] used method of evaluation was criticised for not giving the papers greater consideration based on their correctness, importance, novelty, and overall contribution [23], [24]. On the other hand, this type of evaluation could sometimes easily lead to subjective influences such as the reviewer's competence or bias [25]. Additionally, such evaluation requires a considerable amount of time and effort to adequately review and evaluate each paper. Citations can also play an important role to assess the published work and build on the work of others. Identification, examination, and classification of highly cited research articles are common practices that are frequently adopted in various domains [15]. However, Parnas [23] suggest that citations may sometimes suggest a negative evaluation or can simply be a neutral reference to a general summary of related literature. Knowing that more inclusive and precise methods to examine the contribution of researchers and institutions is a valuable aim, it is still useful and insightful to use the method of rankings based on publication counting [26].

Authors in [2] analysed 691 SE papers that were published in seven well-known SE international conferences and seven well-known SE journals in year 2006 for the aim of identifying the trendy research topics in SE. Additionally, Wohlin [27], [28] carried out two studies to identify the top cited papers in SE journals in years in 2000 and 2001. Their assessment led to the identification of the re-search articles that have the most influence on others

based on the count of citation. In [29], an impact-factor-based approach was adopted to rank SE researchers and institutions in 2007 and presented slightly different results in comparison to the evaluation adopted by Glass and colleagues [9], [10], [12], [13], [18]–[21]. In addition, the authors also developed an online freely available java tool [30] that can be used by other researchers. It can be used to calculate the paper's weight and produce its ranking based on two metrics: impact factors and h-index.

The java tool developed by Ren and Taylor [30] was later used by Garousi and Varma [5] to rank Canadian SE researchers and institutions depending on the values of both; the h-index and impact factor. Additionally, they studied the relationship between the research fund amount gained by each Canadian province and the number of published papers it produces. Glass *et al.* [11] conducted a study to analyse the research and research methods adopted in the SE field in year 2002. The authors analysed 369 papers that were published in six well-known SE journals. Their results suggest that SE research is divers in its topics, narrow in its research approaches and methods, internally focused regarding reference discipline, and technically focused regarding level of analysis.

Another bibliometric study in the SE field was conducted by Garousi and Fernandes [24] and concluded that the number of SE papers that were published since 1968 exceeds 70,000. Furthermore, some SE systematic literature mapping and systematic literature review studies, e.g., [3], [14], [22], [31] conducted a bibliometric evaluation of specific SE areas which include: development of scientific software [3], software mutation testing [14], search-based SE [14], automotive software engineering [22]. A measurement of the number of published SE papers on a country-level was reported by these studies which drew in-sights on SE research trends in the investigated areas.

Garousi and Mäntylä [8] used automated classification of the SE literature citation and topic over the years. Their study concluded that the number of SE research papers published each year has significantly increased and around 6,000–7,000 SE papers are published every year. However, almost half of the published papers are not cited at all. Furthermore, small European countries (population-wise) are the most active in terms of the number of published papers in SE field whereas, only a small share of large countries publishes most of the papers.

According to authors in [4], [24], the SE research body (in DBLP) had 70,000 papers until the year 2014. They primarily examined bibliometrics data and indicated an increase in the authors number of SE papers at an average of 0.40 authors per decade. In addition, their results suggested that most of the examined papers were single-authored until 1980, while articles with 3 or 4 authors reflect almost half of the total SE papers these days. Looking at all the related studies reported above, no bibliometric study was specifically performed to study the KSA-based SE community which leads to the formation of the main goal and contribution of this paper.

### III. RESEARCH METHODOLOGY

#### A. AIM AND RESEARCH QUESTIONS

The aim of this study is to measure the contribution volume of SE research (i.e., number of published papers), produced by KSA-based researchers and institutions, to the SE field. The purpose of this assessment is to rank the produced work of KSA-based researchers and institutions from the point of view of SE prospective researchers, PhD candidates and funding bodies in KSA. According to this aim, the following six research questions (RQ's) were devised:

- RQ 1: What is the annual rate of SE publications in KSA?

The motivation for this RQ is to have a clear idea about the annual growth of SE papers originating from KSA how it compares to SE research publications in the entire world.

- RQ 2: What are the popular subject areas in KSA SE research community?

This RQ is motivated by the need to understand the popular subject areas that are researched by KSA-based SE community. This will help KSA-based researchers and PhD students to wisely select on their research areas and directions.

- RQ 3: Who are the top active authors/researchers in KSA SE research community?

The RQ aims to identify the leading and active re-searcher in KSA SE community. This will help young re-searchers and prospective PhD students to know the active researchers they need to approach for studying in this area.

- RQ 4: What are the leading (i.e. top active) KSA-based institutions in SE research?

Answering this RQ aims to help young researchers and potential PhD students to wisely choose a suitable institution to perform SE research.

- RQ 5: What is the level of collaboration between the KSA-based SE community and the global SE?

Answering this RQ will allow us to measure the collaboration trend between the KSA-based SE community and the international community in the domain of SE.

- RQ 6: What is the citation trend of the SE papers produced by KSA-based researchers?

Answering this RQ will allow us to assess the citation trend of the research produced by the KSA-based SE community and how it compares to other countries. It will also give us the ability to identify the top-cited SE publications originating from KSA and assess the citations distribution of all papers. Additionally, answering this RQ will allow us to measure the effect of publications year, inter-national collaboration between authors, authors affiliations and the number of authors per paper on the citation curve of the KSA produced SE papers.

#### B. DATA SOURCE

There are several data sources to select from for the purpose of conducting a bibliometric study such as ISI Web of Science, Scopus, ACM Digital Library, IEEE Xplore and Google

Scholar. However, to decide which data source to select, the author reviewed several articles that were performed to identify the most comprehensive data sources for bibliometric studies such as [32], [33]. Data sources such as Google Scholar, IEEE Xplore and ACM Digital Library did not appear to provide an extensive search pool. For instance, you can only search papers published by IEEE in IEEE Xplore and the same is in ACM Digital Library where only articles published by ACM can be found. In [32], the authors calculated the correlation of the publication volume by country, based on data from Scopus and the Web of Science. The results indicate that a very high correlation exists ( $R^2=0.99$ ) and scientific production and citations at the country level are largely independent of the studied databases. The author is then has two similar alternatives to select from to perform this study, so Scopus was selected.

Scopus is an abstract and citation database for peer-reviewed literature that contains around 36,377 titles from more than 11,678 publishers, of which 34,346 are peer-reviewed journals in top science fields. In addition, the authors in [34] evaluated the coverage and ease of use of both Scopus and the WoS, and reached that "Scopus is easy to navigate, even for the novice user. The ability to search both forward and backward from a particular citation would be very helpful to the researcher". Additionally, Scopus gives more information about authors such as their affiliations, bibliographic information, references, and the citation received by each of their published work.

#### C. SEARCH METHODOLOGY

The adopted method for extracting the bibliometric data of the published SE papers by KSA-based researchers that are indexed by Scopus, used two search strings to ensure a better coverage of the published papers. In the first search, the author typed the term "software" in the Source Title field of the search page on Scopus, while in the second search the term "software" was entered in the Title field of the search page on Scopus. In the Affiliation Country field, the name of the country "Saudi Arabia" was used for both searches. Figure 1 shows the exact search strings automatically generated by Scopus based on the used search approach in this study. The returned results of the two search strings were then combined, cleaned, checked for redundancy, and prepared for analysis.

To ensure better relevance of the returned SE papers, the author excluded several venues that contained the word "software" in their title but were not actually SE related venues. These excluded venues include journal of Advances in Engineering Software, journal of Optimization Methods and Software, journal of Environmental Modeling and Software, IEEE International Microwave Workshop Series on RF Front Ends for Software Defined and Cognitive Radio Solutions. In addition, the publication year of 2020 was excluded from the search as it was not possible to obtain complete bibliometric data about the whole year during the time this study was of performed (July 2020).

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( TITLE ( software ) AND AFFILCOUNTRY ( saudi AND arabia ) ) AND ( LIMIT-
TO ( SUBJAREA , "COMP" ) ) AND ( EXCLUDE ( EXACTSRCTITLE , "Advances In Engineering
Software" ) OR EXCLUDE ( EXACTSRCTITLE , "Environmental Modelling and
Software" ) OR EXCLUDE ( EXACTSRCTITLE , "2010 IEEE International Microwave Workshop Series On
RF Front Ends For Software Defined And Cognitive Radio Solutions Imws 2010
Proceedings" ) OR EXCLUDE ( EXACTSRCTITLE , "Optimization Methods And
Software" ) ) AND ( EXCLUDE ( PUBYEAR , 2020 ) )

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TO ( SUBJAREA , "COMP" ) ) AND ( EXCLUDE ( EXACTSRCTITLE , "Advances In Engineering
Software" ) OR EXCLUDE ( EXACTSRCTITLE , "Environmental Modelling and
Software" ) OR EXCLUDE ( EXACTSRCTITLE , "2010 IEEE International Microwave Workshop Series On
RF Front Ends For Software Defined And Cognitive Radio Solutions Imws 2010
Proceedings" ) OR EXCLUDE ( EXACTSRCTITLE , "Optimization Methods And
Software" ) ) AND ( EXCLUDE ( PUBYEAR , 2020 ) )
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FIGURE 1. Scopus automatically generated searching and filtering strings.

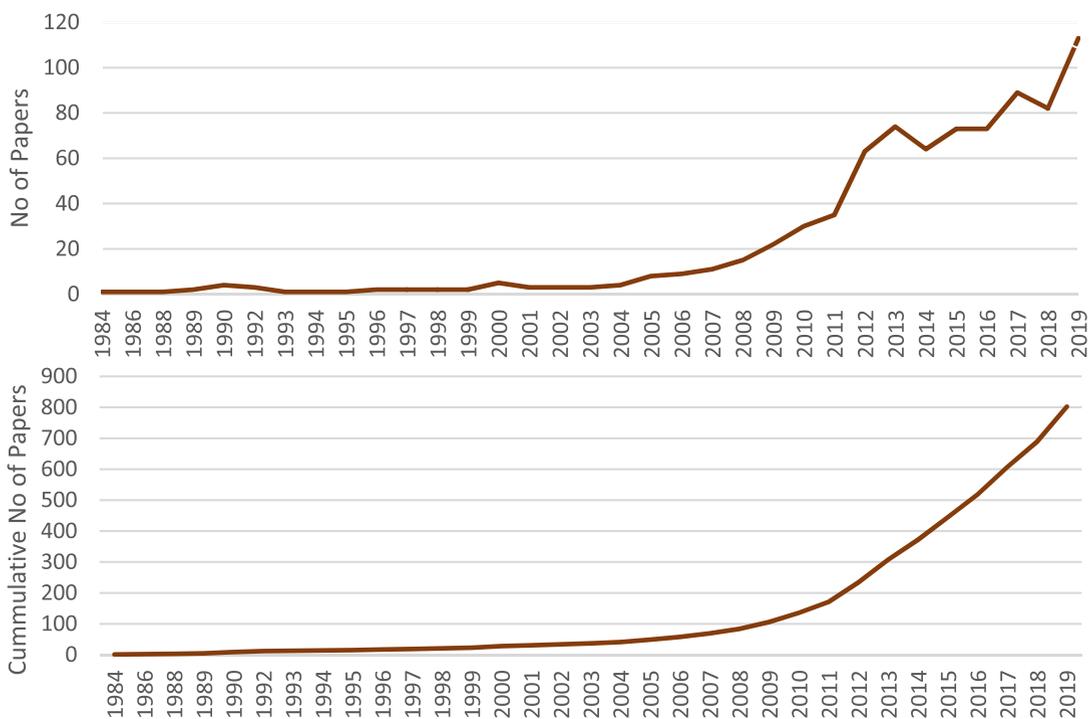


FIGURE 2. Individual (top) and cumulative (bottom) values of the annual publication trend of the resulted papers.

The author also made sure the search included popular major SE conferences such as; International Conference on Software Engineering (ICSE), ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering (ESEC/FSE), International Symposium on the Foundations of Software Engineering (FSE), International Conference on Automated Software Engineering (ASE) and International Conference on Software Maintenance (ICSM). Furthermore, an additional step was taken to further ensure relevance of the returned papers. The author randomly selected three papers from the publications list of two active SE Saudi authors (Alyahya, Sultan and Alenezi, Mamdouh). The selected papers were then checked for inclusion in the re-turned search results and the verification results were positive.

The search process resulted in 802 papers published between years 1984-2019. These papers were then used for the bibliometric analysis reported in this paper. The data used for this study is available for download and repeatable analysis at: <https://bit.ly/3IU9EmJ>.

IV. FINDINGS

This section presents the findings of this study which are organized according to the RQs discussed previously.

A. RQ1: ANNUAL PUBLICATION TREND

Figure 2 shows both individual and cumulative plots of the annual trend of published SE papers by KSA-based researchers. To put this publication annual trend data in context, Figure 3 shows the world-wide annual trend

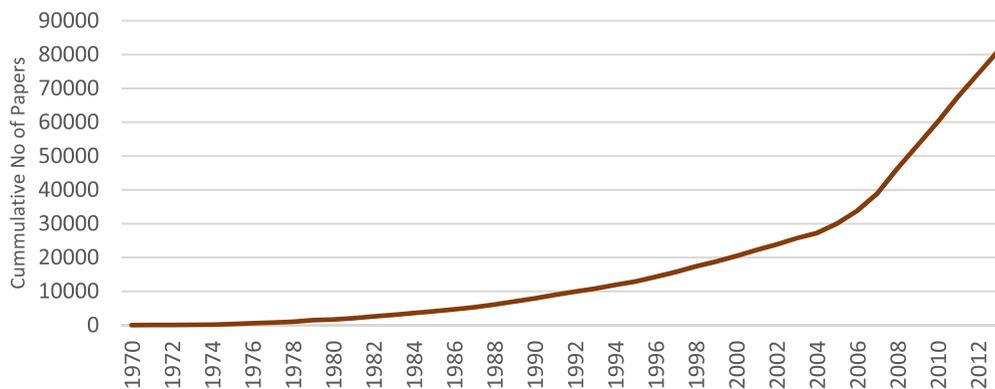


FIGURE 3. A cumulative annual publication trend of SE papers worldwide [8].

of SE papers publication between years 1968-2014 as reported by a world-wide SE bibliometric study published in 2015 [8].

The KSA-based SE research community was not very productive until the year 2007. Between years 1984-2006, the publication rate was at its lowest (less than 10 papers a year). From 2007 onwards, the trend has been growing in a healthy rate reaching 113 published papers in 2019. In comparison to the world-wide cumulative trend, it can be seen the KSA cumulative trend reflects a similar growth rate to the world-wide trend. Additionally, the author investigated the KSA SE community’s research contributions to the world-wide SE publications. To get an estimate of this, in the source title field of Scopus database, a search for the word “software” without limiting the search to a specific country was done. This resulted in 128,344 Scopus indexed SE-related papers. Dividing the KSA SE publication volume (802 papers) by that number, it is estimated that KSA only produces around %0.62 of the world-wide SE knowledge which is a minor contribution regrettably.

The results also indicate that the ratio of journal versus conference publications that are made by KSA-based re-searchers does not agree with the SE international ratio (see Figure 4). Internationally, the publication ratio of SE papers in journals is around 34% and 66% in conferences. However, the ratio is different in KSA as 42% of the published SE papers appeared in journals and 51% of them appeared in conferences proceedings. This trend of giving more value to journals in KSA does not agree with the international ratio, not only in SE community, but in Computer Science community in general [4], [35]. This is probably caused by the research and publication policies that are followed by institutions in the country where they tend to give more weight (in terms of publication quality) to journals over conferences publications regard-less of the research domain. This encourages decision and policy makers at the research institutions (e.g., universities) to review the current research and publication policies to make them adaptive to the nature of SE research were conferences are highly valued by the international community of SE and can produce high quality publications.

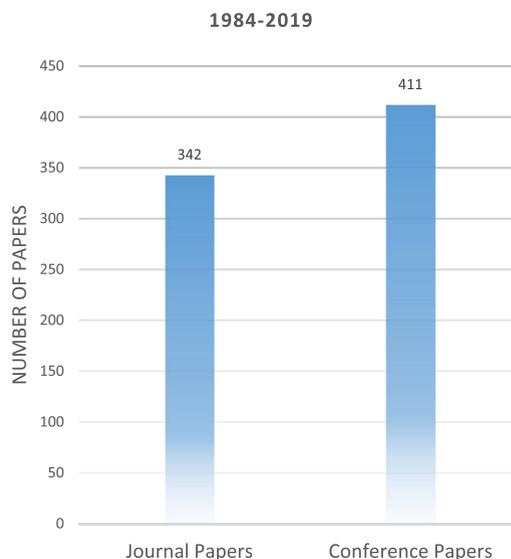


FIGURE 4. Number of published papers by KSA-based SE researchers (conferences vs. journals).

TABLE 1. Top common terms in the collected papers titles.

Terms	Papers count	% of all papers
Model	126	16%
Development	81	11%
Process	63	8%
Requirements	57	7%
Analysis	53	7%
Design	52	7%
Networks	45	6%
Framework	40	5%
Quality	32	4%

**B. RQ2: POPULAR SUBJECT AREAS**

To provide a visual view of the popular SE subject areas researched by KSA-based SE community, the author created a word cloud based on the titles of all the papers as presented in Figure 5. English terms that are common (such as “software”) were omitted for clarity and brevity. Table 1 shows

**TABLE 2. The most active authors, research areas and affiliation (top 10).**

Rank	Name of Author	Former/current Affiliation	Research areas
1	Mohammad Alshayeb	King Fahd University of Petroleum and Minerals	Empirical software engineering, Software refactoring, Software measurement and metrics, Software quality, Evidence based software engineering
2	Mahmood Niazi	King Fahd University of Petroleum and Minerals	Evidence-based software engineering, Global software engineering, Empirical software engineering, Software process improvement
3	Sajjad Mahmood	King Fahd University of Petroleum and Minerals	Global software engineering, Process improvement and modelling, Requirements engineering
4	Hanene Ben-Abdallah	<ul style="list-style-type: none"> <li>Former affiliation: King Abdulaziz University</li> <li>Current affiliation: Higher Colleges of Technology in UAE</li> </ul>	Software design quality, business process deployment in the cloud, reuse techniques in software and business process modelling
5	Moataz Ahmed	King Fahd University of Petroleum and Minerals	software testing, software metrics and quality models, software reuse and cost estimation.
6	Mahmoud Elish	<ul style="list-style-type: none"> <li>Former affiliation: King Fahd University of Petroleum and Minerals</li> <li>Current affiliation: Gulf University for Science and Technology, Kuwait</li> </ul>	object-oriented analysis and design, empirical software engineering, software maintenance and evolution, computational intelligence in software engineering, software metrics and measurement
7	Mohamed El-Attar	<ul style="list-style-type: none"> <li>Former affiliation: King Fahd University of Petroleum and Minerals</li> <li>Current affiliation: Alfaisal University</li> </ul>	use case models, human aspects in software modelling, model consistency assurance, secure software engineering, model transformation
8	Sultan Aljahdali	Taif University	Reverse Engineering, Soft Computing for Software Engineering, Software Testing, Computer Security, Developing Software Reliability Models
9	Mamdouh Alenezi	Prince Sultan University	Software Quality, Software Metrics, Quality Attributes and Evolution, Software Maintenance
10	Jameleddine Hassine	King Fahd University of Petroleum and Minerals	Requirements engineering, Software Maintenance, Formal Verification and Validation of distributed systems, Communication protocols, Formal Semantics

the most recurrent terms that appeared in the titles of all the papers. The results suggest that the most popular subject areas in the KSA-based SE community are software; modeling, development, processes, requirements, analysis and design. However, the results also suggest that some SE subject area are less popular such as software testing, software maintenance and evolution, software adaptation, etc. This highlights the necessity for more diversity in the researched SE subject areas among the KSA-based SE researchers.

### C. RQ3: ACTIVE AUTHORS

The authors list obtained from Scopus for this study had to be further analysed and cleaned to address some naming issues as some authors used different naming styles in some papers and not in others (e.g., the use of different last names). Figure 6 presents the ranking of the most KSA-based SE active authors who published six or more papers. It is also important to highlight that Saudi nationals forms only 20% of the most active authors in the domain of SE in KSA. This indicates a shortage of SE Saudi researchers and sheds the

light on needs for more investment (in people and resources) in this highly important domain by decision makers in the education and research sectors in KSA. Additionally, there is a clear lack of Saudi female researchers in the SE domain which highlights the need for more investigation into the reasons behind that and calls for more support to the role of women in this domain by decision makers.

To help prospective SE postgraduate students and researchers in KSA deciding their path and building a re-search collaboration network, it is essential to highlight the current affiliations and research interests of the most active SE authors (see Table 2). The table shows that three of the top-10 active SE researchers changed their affiliation and moved out of KSA. It is also interesting to see that seven of the top-10 active authors are or were affiliated to KFUPM.

### D. RQ4: ACTIVE INSTITUTIONS

Figure 7 shows the active Saudi institutions in the domain of SE research in terms of the volume of published papers. It can be seen that King Fahd University of Petroleum and



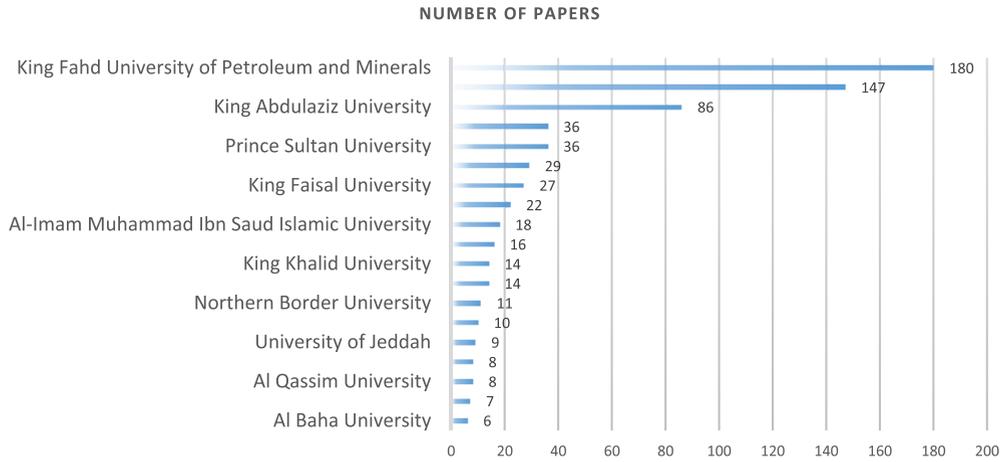


FIGURE 7. Active institutions according to the number of papers they produced.

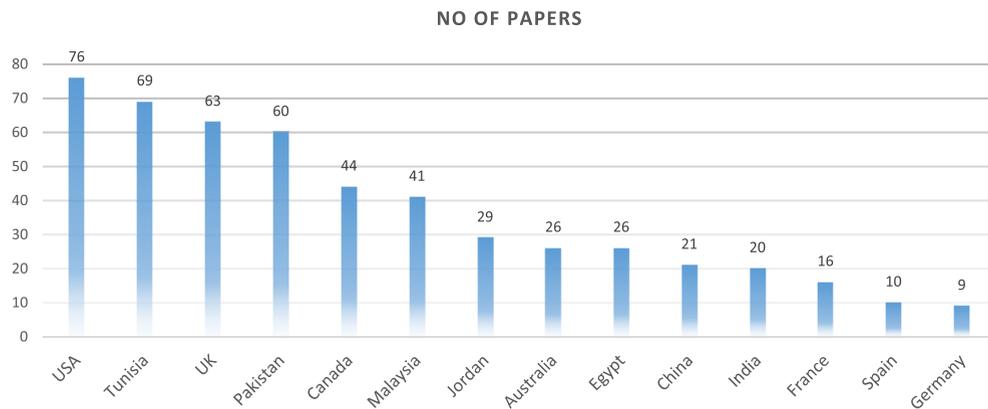


FIGURE 8. Countries whose researchers co-authored papers with KSA-based SE researchers.

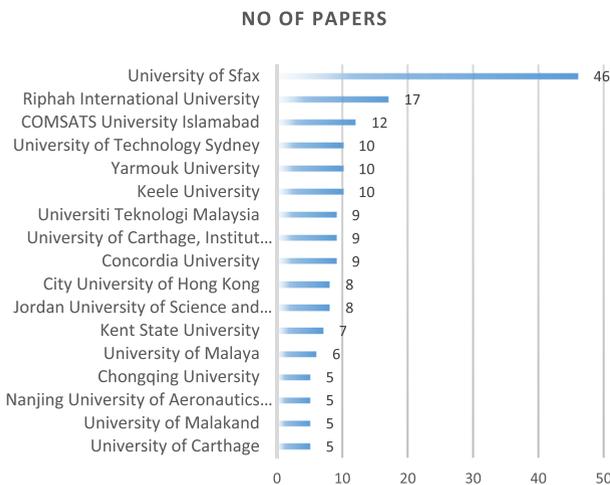


FIGURE 9. Institutions whose researchers co-authored papers with KSA-based SE researchers.

cited papers were internationally-authored which could indicate a positive correlation between the citation number and the international collaboration between authors [16], [39]. It is also apparent that the authors of almost all the top cited papers were affiliated to the top two active institutions as

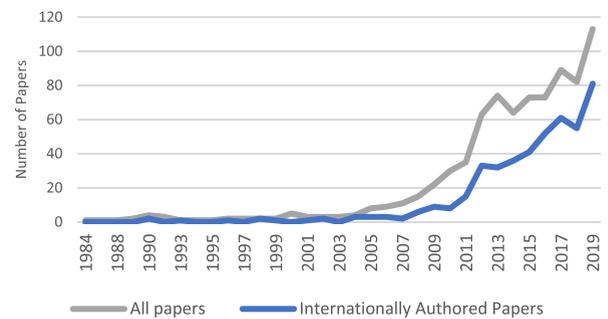


FIGURE 10. KSA SE paper' annual trend of internationally-authored versus all papers.

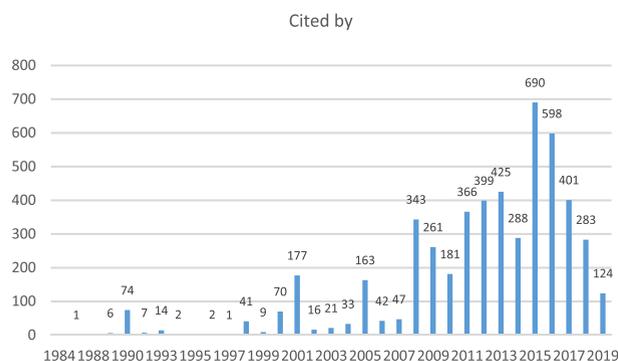
previously shown in figure 7. This could indicate a positive correlation between the rank of the authors institution and the number of citations the published papers receive [39].

1) RQ 6.1: CITATIONS VERSUS PUBLICATION YEARS

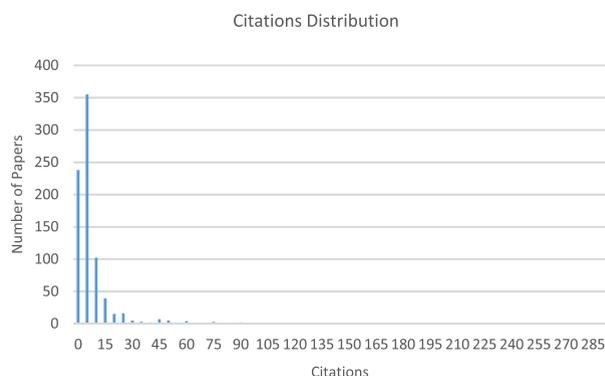
To have an overview of the citations trend over the years (1984-2019) of the published SE papers originating from KSA, figure 11 shows the annual number of citations that were received until the time of writing this study. The general trend shows a modest increase between years 1984-2007

**TABLE 3. The ten most cited papers authored by KSA-based authors.**

Paper's Title	Year	Venue	Cited by	Annual average	Authors (KSA-based authors in <b>Bold</b> )
Predicting defect-prone software modules using support vector machines	2008	Journal of Systems and Software	284	23.6	<b>Elish K.O., Elish M.O.</b>
ERP software implementation: An integrative framework	2001	European Journal of Information Systems	174	9.2	Al-Mudimigh A., Zairi M., <b>Al-Mashari M.</b>
Software defect prediction using ensemble learning on selected features	2015	Information and Software Technology	130	26	<b>Laradji I.H., Alshayeb M., Ghouti L.</b>
A distributed access control architecture for cloud computing	2012	IEEE Software	102	12.75	Almutairi A., Sarfraz M., <b>Basalamah S.</b> , Aref W., Ghafoor A.
Barriers in the selection of offshore software development outsourcing vendors: An exploratory study using a systematic literature review	2011	Information and Software Technology	89	9.8	Khan S.U., <b>Niazi M.</b> , Ahmad R.
Securing software defined networks: Taxonomy, requirements, and open issues	2015	IEEE Communications Magazine	86	17.2	Akhunzada A., Ahmed E., Gani A., <b>Khan M.K., Imran M., Guizani S.</b>
Factors influencing clients in the selection of offshore software outsourcing vendors: An exploratory study using a systematic literature review	2011	Journal of Systems and Software	83	9.2	Khan S.U., <b>Niazi M.</b> , Ahmad R.
Risks and risk mitigation in global software development: A tertiary study	2014	Information and Software Technology	74	12.3	Verner J.M., Brereton O.P., Kitchenham B.A., Turner M., <b>Niazi M.</b>
Security in Software-Defined Networking: Threats and Countermeasures	2016	Mobile Networks and Applications	72	18	Shu Z., Wan J., Li D., Lin J., Vasilakos A.V., <b>Imran M.</b>
Lower Bound on the Number of Processors and Time for Scheduling Precedence Graphs with Communication Costs	1990	IEEE Transactions on Software Engineering	72	2.4	<b>Al-Mouhamed M.A.</b>



**FIGURE 11. Showing the current number of citations to papers over the years 1984-2019.**



**FIGURE 12. Citation distributions for all the SE papers authored by KSA-based researchers.**

and then a healthier trend emerged reaching its heist level in 2015 and 2016. From 2017 onwards, there is decrease in the number of citations and this can be caused by the recency nature of these publications and this could positively change over time.

In addition, figure 12 shows the citation distributions for all the SE papers authored by KSA-based researchers. In general, a wide range of variances in citations distribution can be noticed. Around 30% of all the papers did not receive any

citation at all (238 papers) and around 28% of the papers received one citation only (222 papers). This indicates that more than half of the papers (58%) were either uncited or cited once only. In addition, 38% (309 papers) of all the papers received a number of citations between 2-5 whereas the papers that received more than five citations form only 4% (32 papers) of the all the SE papers authored by KSA-based researchers. This sheds the light on the need for further investigation into the causes and issues behind the modest

**TABLE 4.** Citation numbers and averages for se papers in four countries.

Country	Papers count	citations count	Average citations/paper
KSA	802	5085	6.3
Egypt	471	1983	4.2
Jordan	525	3257	6.2
UAE	442	3463	7.8

level of citations received by KSA SE papers and the possible ways to address these issues.

To give a more meaningful view of the number of citations received by SE papers authored by KSA-based re-searchers, a comparison of the number of the number of papers and citations (at the time of writing this study) with three KSA neighbouring countries (Egypt, Jordan and United Arab Emirates) is provided. The data for each country was obtained from Scopus database following the same method used to obtain the bibliometric data of this study. Table 4 shows the number of SE papers, number of citations and the average citation per paper for each country. The results indicate that KSA produced the highest number of papers (802) and received the highest number of citations (5085) among the other three countries. Jordan comes second in the number of published SE papers (525) but the third in the number of citations received (3257). The third country based on the number of published SE papers was Egypt (471 papers) but the last in the number of received citations (1983) whereas UAE has the least number of SE papers (442) but received the second highest number of citations (3463).

However, averaging the number of citations each paper received can change the position of each country. The average number of citations per paper in each country is as follows, UAE (7.8), KSA (6.3), Jordan (6.2) and Egypt (4.2). In general, KSA is performing well comparing to its neighbouring countries with the first place in the number of published papers and the total number of citations and the second place in the average number of citations each paper received. However, in comparison to developed countries such as the United Kingdom or Germany where the average citation per an SE paper exceeds ten citations, more work on the quality and visibility of the SE papers authored by KSA-based researchers are needed.

## V. THREATS TO VALIDITY

The following potential threats to validity for this study were identified:

- Bias in the selection of bibliometric data for this study could have been resulted. However, to address this threat, the author chose the Scopus database which is one of the most well-known and comprehensive data sources [33], [34]. Further-more, to overcome any potential research bias, no interpretations of the returned results were made as all performed analysis was purely quantitative.

- The search method adopted in this study could have returned papers that do not necessarily fall under the domain of SE. To mitigate this threat, a random selection of the resulted papers was per-formed, and fifty selected papers were assessed against their relevance to SE and all of them were found to be in the domain of SE.
- Moreover, the search method adopted in this study could have overlooked some KSA-based SE authors. To address this threat, a selection of five names of well-known KSA-based SE authors were performed and then checked for their inclusion in the returned results. All selected authors' names were found to be included in the re-turned search results.
- Additionally, the search method adopted in this study is completely repeatable as all returned da-ta is made available by the author and the steps of the search method were clearly described.

## VI. CONCLUSION

Bibliometric studies such as [2]–[21] are common in the field of SE for measuring and analysing publications in the area. However, the focus of this study is on the publications' trends and contributions in the KSA-based SE community. The study analysed the bibliometric data of 803 papers published by KSASE community to answer six related research questions. The study revealed insightful results on the KSASE community size of contribution to the field of SE between years 1984–2019. The assessment is meant to help SE Saudi researchers, PhD students and practitioners to wisely select their potential future re-search areas. The study will also help the KSA SE community to recognize strengths, weaknesses and opportunities in this area. The results can also support funding authorities and research decision makers in the domain to exploit the opportunities for improvements highlighted by this study. It is important to highlight that the nature of this study is highly quantitative. The qualitative impact of the contribution of the KSA SE community to the domain of SE is hard to measure. This sets the path for future re-search in this area.

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