Implementing Artificial Intelligence Tools for Risk Management in Software Projects

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In recent years, there has been a significant surge in interest in the incorporation of artificial intelligence (AI) within the field of software engineering. This phenomenon can be attributed to the fact that AI has become ubiquitous and increasingly accessible, thereby finding effective application across various pivotal facets of software systems. Its contribution extends not only to the creation of novel functionalities but also to the enhancement of existing processes within software projects, often resulting in substantially improved adaptability to specific user requirements. Within this paper, we provide an overview of the application of AI tools within one of the critical domains of software project management - risk management. To achieve this objective, a bibliometric analysis of literature pertaining to risk management in software projects employing AI tools has been conducted. The primary aim of this study is to identify and analyze key trends, authors, journals, and keywords within this multidisciplinary domain, in order to gain a better understanding of the progress and relevance of research concerning risk management in software projects utilizing AI tools. The methodology encompasses a review of pertinent databases and the identification of relevant publications using keywords associated with software projects, risk management, and artificial intelligence. Quantitative parameters such as the number of published works, author collaborations, citation frequency, and the distribution of articles over time and across journals are analyzed.

Key Words: *software projects, risk, risk management, artificial intelligence, Web of Science, bibliometric analysis*

1. INTRODUCTION

In the conditions of modern business characterized by rapid market changes and intense competition, most companies organize their operations through project implementation. The software industry is no exception, as numerous software projects are present in the market.

The value of the global software industry in 2022 was estimated at $8,179.48 billion [1], while the value of the software industry in Serbia was estimated at approximately $795 million for the same period [2]. Based on the presented data, it is clear that the software industry not only holds immense global value but also represents a key growing sector of the world economy.

However, despite the growing trend of executing software projects, nearly 80% of them are characterized as unsuccessful. Various studies on the preva¬lence of software project failures demonstrate different success factors over the years [3], wherein risk management in the execution of these projects stands out as a leading factor in their failure.

The main aim of this paper is to analyze the potential of using artificial intelligence tools in the domain of managing risks in software projects. The paper is structured into three chapters.

Firstly, it presents the state of the field through a review of the literature as a basis for further research direction. The research involves a bibliometric analysis of a sample of works from the Web of Science database, while the final chapter encompasses a review of the conducted research, a discussion of the obtained results, conclusions, definition of the limitations of the existing research, and directions for future research.

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2. LITERATURE REVIEW AND STATE OF THE FIELD

In this section of the paper, attention will first be devoted to a literature review in the domain of risk, the general risk management process, and the specific management of risks in software projects, as well as the most common risks in software projects. Additionally, focus will be placed on artificial intelligence and its application in this field. Risk is a concept encountered daily in both business and private life. What is intriguing is that, despite the growing attention dedicated to this field, there is no universally accepted, theoretically and practically confirmed definition of risk. Given that everything to some degree unknown and uncertain is associated with risk, and projects represent business ventures unfolding in the future [4], a certain level of uncertainty, and thus the risk of failure, is closely linked to project realization [5]. To comprehend the specifics of the concept of risk and its understanding in various business and scientific disciplines, as well as over time, a table has been compiled. This table chronologically presents the definitions of the concept of risk by different authors in different periods [6, 7].

Table 1. Definition of term risk, modified according to [6,7]

Year	Author	Definition
1976.	*Kaufmann*	*Risk is a measure of the probability and severity of unwanted events.*
1981.	*N. Kaplan*	*Risk depends on three variables (si, pi, ci), where si is the scenario, pi is the probability of the i-th scenario, and ci is the consequence of the i-th scenario, i=1,2,..,N.*
2002.	*ISO/IEC Guide* 73	*Risk is a combination of the probability of an event and its consequences.*
2009.	*ISO31000* standard	*Risk represents the effect of uncertainty on objectives.*
2010.	*Petrović et al.*	*Risk is an uncertain event or condition that, if it occurs, has a positive or negative impact on project objectives.*
2015.	*The Economic Times*	*Risk implies future uncertainty regarding deviations from expected earnings or anticipated outcomes.*
2015.	*Association for Project Management*	*Risk is the exposure of stakeholders to the consequences of variations in outcomes resulting from the accumulation of individual risks along with other sources of uncertainty.*
2015.	*PRINCE2*	*Risk is an uncertain event or set of events that, if it occurs, will affect the achievement of goals.*
2017.	*PMI*	*Risk represents the effect of uncertainty on project and organizational objectives.*

The success of managing the entire project can be measured by the number of risk events that occurred in the project, as well as the magnitude of the impact their realization had on the project [5]. One of the most well-known methodologies for project risk management, applicable to software projects, is proposed by PMI (Project Management Institute) in its PMBOK [5]. This methodology includes the following subprocesses: Risk management planning, Risk identification, Qualitative risk analysis, Quantitative risk analysis, Risk response planning, and Monitoring and controlling risks. In addition to this, the management of risks in software projects can be defined as a set of coordinated activities that enable the project to be directed and controlled regarding risks [8].

However, despite the progress that risk management in software projects has experienced in the last decade and the positive effects it has had on managing large and complex software projects, there has been little attempt and progress in developing models that indicate the measures management should take to improve the chances of successful project completion [9]. In the realm of managing risks in software projects, two common challenges hinder the process. Firstly, risk assessment is often subjective, relying heavily on the project manager's perspective, overlooking standardized methodologies and prior project experiences. Additionally, many development teams view risk management as a wasteful endeavor, complicating its implementation. Secondly, conventional risk management methods, typically analytical, struggle to address the intricate complexities inherent in software projects. These challenges persistently drive the need for refining risk management strategies in the software industry.

Top of FormIt is significant to consider categories of risks that most commonly occur in software development projects. One possible approach proposed in the reviewed literature is the categorization of risky events concerning the phases of software development projects. All software, in general, goes through the same development cycle, so risks are categorized concerning the five phases of software development projects: planning, analysis, design, implementation, and maintenance [10]. Ten of the most common risks that occur in software projects have been identified:

- Gold-plating of software projects;
- Lack of adequate technical management;
- Inadequate identification of software project requirements;

- Lack of knowledge about technologies, tools, and programming techniques;
- Unclear, inaccurate, and/or incomplete requirements that change constantly and rapidly;
- Initial requirements changing after the planning phase of the software project;
- Lack of detailed analysis of requirements;
- Harmful competitive actions;
- Change in specifications of the software project;
- Inefficient communication system in the software project.

Based on the presented list, several interesting conclusions can be drawn. First, even 80% of risky events, namely the eight listed, belong to the analysis phase of software projects. Also, the risk that is ranked first is the gold-plating of software projects, which involves adding any feature that was not considered in the original plan and scope of the project [11] or product description [12].

Artificial Intelligence (AI) is an essential concept in various industries worldwide. According to the Oxford definition, artificial intelligence is defined as the theory and development of computer systems capable of performing tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation of different languages [13]. It can be said that artificial intelligence represents a knowledge project that takes knowledge as a subject, acquires it, analyzes and studies methods of expressing knowledge, and ultimately uses these approaches to achieve the effect of simulating human intellectual activities [14].

The presence of artificial intelligence in all areas of business can be illustrated by the results of a study conducted by Zoom info [15]. As much as 47% of digitally mature organizations say they have an established artificial intelligence strategy, while 64% of managers emphasize that investments in artificial intelligence have already increased their profit, and 61% of companies believe that using artificial intelligence has helped them identify opportunities that might otherwise have been missed. Also, the results of the aforementioned study have shown that 83% of companies say that investing in artificial intelligence is a strategic priority for them. As a result, the artificial intelligence industry is expected to reach $190 billion by 2025, with global spending on artificial intelligence systems reaching $57 billion by the end of 2022. The project management domain is no exception.

Artificial intelligence improves risk assessment by understanding the occurrence of risks in a specific project context [16]. Namely, the combination of machine learning with Monte Carlo simulation, applied in the analytical approach to risk management, can help improve risk assessment and simulation in the project risk management process [17].

The latest artificial intelligence technologies have the potential to fundamentally transform risk management [18]. Besides significantly reducing operational costs, these and other technologies can provide new opportunities for the risk management process, including incorporating controls and monitoring directly into processes, prioritizing areas for testing and monitoring, applying automated boundary monitoring with defined escalation, solving problems in real-time to improve overall risk awareness, and providing decision support in the decision-making process [18].

3. METHODOLOGY

A properly grounded methodological framework enriches the content of the paper, simultaneously increasing its utility and contributing to the research's practical value. In this regard, it is essential to precisely define the methodological framework as it describes all the steps of the process, including applied procedures and approaches.

In Figure 1, a schematic representation of the research methodology is provided, commencing with an introduction and an overview of the industry's current state. Following this is the research section, comprising the establishment of the theoretical foundation of concepts, bibliometric analysis, presentation and interpretation of the analysis results, and drawing conclusions. This process concludes by directing the future course of the research, aiming to emphasize the necessity of continuity in the investigation.

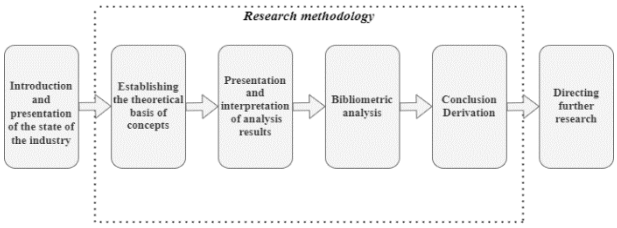

Figure 1 - Schematic representation of the research work methodology

After the introduction and a review of the literature and the state of the field, a bibliometric analysis was conducted based on academic publications related to risk management in software projects and the application of artificial intelligence tools. For the purpose of this analysis, a procedure consisting of four steps was applied [19]:

- Definition of appropriate keywords and logical operators;
- Analysis of initial search results;
- Adjustment of the search according to the specified quality criteria;
- Presentation of trends in the field.

The Web of Science (WoS) database was utilized to conduct this process. Web of Science is a leading global platform for searching scientific citations and analytical information. It serves as a research tool supporting a wide range of scientific tasks in various knowledge domains and provides a dataset for studies with extensive data [20].

4. RESULTS AND DISCUSSION

Based on the literature review and the state of the field, the research included a search for the keywords „software projects", „risk management", and „artificial intelligence" within the Web of Science database. The query used was as follows: ((ALL=(software projects)) AND ALL=(risk management) AND ALL=(artificial intelligence)). The applied query included combinations of terms in the title, abstract, and keywords, as indicated by the use of „ALL". The database resulted in a total of 115 results from 2000 to 2023. Due to the narrowed number of papers, further adjustments to the research were not made, and all results entered the bibliometric analysis. The Bibliometrix R package was used, providing valuable insights into the evolution of this research field. The analysis identified key contributions to the development of this field, including authors, institutions, sources, countries, documents, and references. Bibliometrix offers a comprehensive set of tools for conducting fundamental bibliometric analysis, adhering to a rigorous scientific mapping process [20].

On a sample of 115 papers in the field of applying artificial intelligence tools in risk management in software projects, an annual growth rate of 7.69% was observed from 2000. to 2023. The average number of citations per document is 5.77, with a total of 3.441 references. Concerning authorship, it is interesting to note that 369 different authors were identified, with 11 papers authored by a single author, the number of co-authorships per document being around 4, and the percentage of international co-authorship being 26.09%.

Next, trends in publishing papers across domains were considered, as shown in Figure 2.

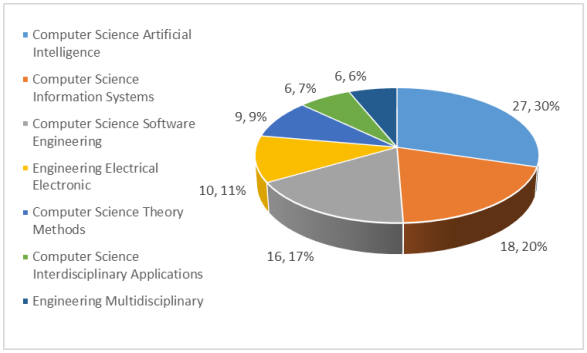

Figure 2 - Publishing trends by area

Leading with almost 30% is Computer Science Artificial Intelligence, followed by Computer Science Information Systems at 18% and Computer Science Information Systems at 16%. Additionally, Engineering Electrical Electronic ranks at 10.11%, Computer Science Theory Methods at 9.9%, Computer Science Interdisciplinary Applications at 6.7%, and Engineering Multidisciplinary at 6.6%.

It is interesting to examine the distribution of the number of papers over the years, as depicted in Figure 3. It can be observed that the number of published scientific papers on the application of artificial intelligence tools in risk management in software projects experienced its first growth in 2008 when 6 papers were published. The subsequent increase to 8 published papers was recorded in 2013, with the popularity of this topic diminishing until 2020. from 2020. to the present, 13, 14, 12, and 11 papers have been published, respectively, representing approximately half of all papers published in this field to date.

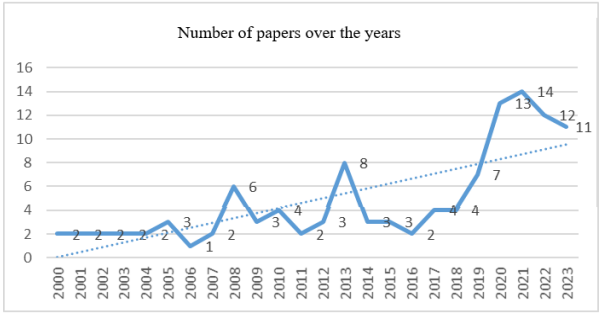

Figure 3 - The trend of publication of papers for the period from 2000 to 2023

The analysis of the three-field plot was used to examine the relationships between 20 different countries, an equal number of authors, and keywords within the field of applying artificial intelligence tools in risk management in software projects, as illustrated in Figure 4. This analysis explores the connections and collaboration between countries, indicating the level of international engagement and knowledge sharing in this field. Additionally, identifying 20 key terms reflects fundamental concepts and themes present in the analyzed literature.

The height of the square nodes is proportional to the frequency of occurrence of a specific country, author, or keyword within the collaboration network. The width of the lines between nodes is proportional to the number of connections. Figure 4 shows that China (frequency=54.0) is the country with the highest number of connections, followed by Spain (frequency = 44.0) and Turkey (frequency = 35.0). Within China, the most influential authors in the considered field are L. Zhang, Z. Iv, Q. Wang, X. Wu, and Y. Xu. Next, within Spain, the most influential authors are R. Albuquerque, M. Chavez, J. Macias-Bernal, P. Ortiz,

R. Ortiz, and J. Prieto, while within Turkey, it is M. Akcayol and M. Calp. Regarding keywords in papers originating from China, the following keywords are prevalent: risk management, artificial intelligence, software, machine learning, software engineering, project management, intelligence, artificial, software projects, project planning. On the other hand, in Spanish papers, dominant keywords include artificial intelligence, software, software engineering, project management, management, project, agile methodologies, risk, fuzzy logic, and expert systems, while in Turkish papers, the dominant keywords are risk management, software, software engineering, management, agile methodologies, Scrum, software project management.

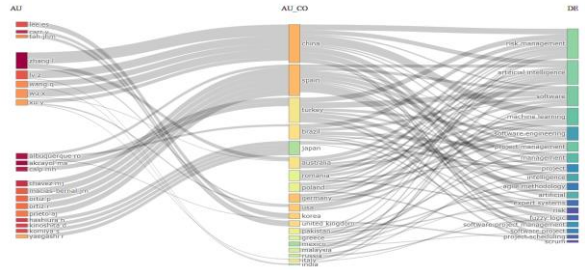

Figure 4 - Three-field plot. Middle field (Countries): Number of items (1–20), Left field (Authors): Number of items (1–20), and Right field (Key words): Number of items (1–20). Maximum number of items (1–50).

Furthermore, it is important to consider the most relevant sources in the field of applying artificial intelligence tools to risk management in software projects. To this end, an examination was conducted to identify the journals and conference proceedings that publish papers on the application of artificial intelligence tools in the domain of risk management in software projects. Interestingly, in the sample of searched papers, it is challenging to discern dominant journals and conference proceedings because the number of published scientific papers is evenly distributed in the observed database. At the top of the list are the proceedings of the 15th International Conference on Enterprise Information Systems with 3 published papers, followed by Advances in Engineering Software, Knowledge-based Software Engineering, Sustainability, New Trends in Software Methodologies, Tools and Techniques, Artificial Intelligence and Applied Mathematics in Engineering Problems, Knowledge-based Software Engineering, IEEE Access, New Trends in Intelligent Software Methodologies, Tools and Techniques, and Applied Sciences Basel, each with 2 published papers in each of the aforementioned sources.

Additionally, it is important to examine the most influential authors, institutions, and countries publicshing papers in the field of applying artificial intelligence tools for risk management in software projects. Regarding the most influential authors in this field, Zhang L. stands out with 5 published papers, followed by authors who are tied with 2 published papers each.

Next, it is interesting to compare the most influential institutions and countries in terms of publishing papers in this field. Regarding the most influential institutions, the University of Technology Sydney is at the top with 6 published papers, followed by the Electrical Engineering University in China and the University of Seville with 5 published papers each. Also notable are universities in China, Turkey, and Brazil. Figure 5 shows the most influential institutions in terms of published papers in the field of applying artificial intelligence tools for risk management in software projects.

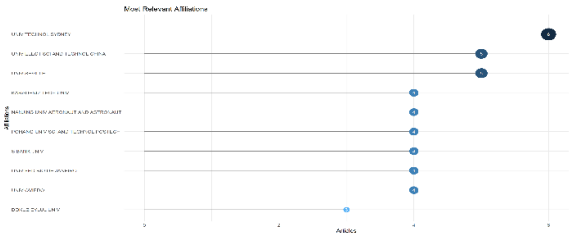

Figure 5 - The most influential institutions with the number of published works

On the other hand, China stands out as the most influential country in terms of the number of published papers in this field, with a considerable 75 articles, followed by Spain with 31 and Germany with 28. In addition to them, the top 10 also include the United States with 22, South Korea with 19, the United Kingdom with 18, Brazil with 17, Australia and Turkey with 14, and Italy with 13 published papers. Table 3 shows the most influential countries by the number of published articles, as described earlier.

Table 2. The most influential countries with the number of articles published

Country	Number of articles published
China	75
Spain	31
Germany	28
USA	22
South Korea	19
United Kingdom	18
Brazil	17
Australia	14
Turkey	14
Italy	13

Figure 6 illustrates the trend of publishing papers on the application of artificial intelligence tools in risk management for software projects. It is possible to

observe an upward trajectory after 2018 in China, as well as after 2020 in Germany.

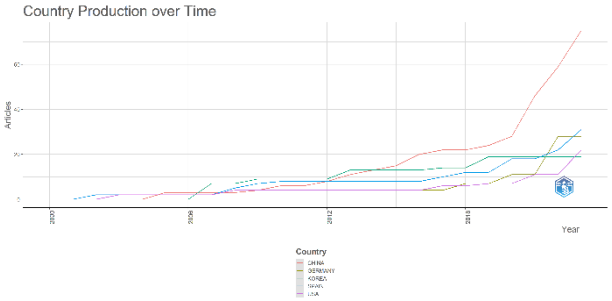

Figure 6 - Publication trend by country over the years

However, in terms of citation impact, the order of countries is different. The United Kingdom ranks first with a score of 291, followed by China with 164 and Iran with 55. Figure 7 illustrates the countries based on the number of citations.

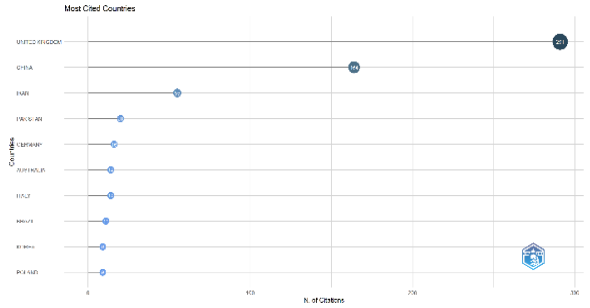

Figure 7 - The most cited countries

When analyzing the most frequently used terms in literature dedicated to the application of artificial intelligence tools in managing risks in software projects, it is notable that the term „management“ occupies the first position among the most frequent concepts. This key term reflects the significance of effective leadership and project risk management in the software industry.

Subsequently, the analysis shows that the terms „risk“ and „model“ are also highly positioned on the list of most commonly used terms. This indicates the central role of understanding, identifying, and managing risks in the software development process, as well as the importance of modeling risks as a means of assessing potential issues.

Additionally, the terms „framework“, „prediction“, and „systems“ also stand out among the prevalent concepts. „Framework“ suggests the importance of using methodological and analytical frameworks in the risk management process, while „prediction“ points to the application of predictive models to anticipate future risks. „Systems“ refer to complex information technologies and software platforms used to facilitate risk management in software projects.

Figure 8 illustrates these terms and their frequency of occurrence.

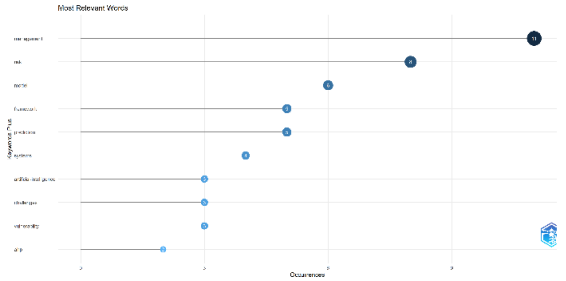

Figure 8 - The most frequently used words in papers

5. CONCLUSION

Based on the bibliometric analysis, it can be concluded that effective risk management is one of the main priorities of software projects [8]. There has been a growing trend in publications in recent years, implying the potential application of artificial intelligence tools independently or in conjunction with existing analytical approaches.

The application of artificial intelligence in risk management for software projects brings numerous benefits, including early risk recognition, improved decision-making processes, automated risk monitoring and analysis, and systemic thinking [21]. The key challenge is integrating artificial intelligence into existing project management methodologies to achieve a synergistic effect and enhance the efficiency of risk management for software projects.

As a comprehensive conclusion, it is crucial to emphasize that the proposed strategies for implementing artificial intelligence tools should harmoniously coexist with existing risk management approaches in the context of software projects. This does not promote the rejection and replacement of existing analytical methods but their enhancement through the integration of analytical tools and methodologies with artificial intelligence tools, employing systems thinking and creating a holistic framework for managing risks in software projects with multiple dimensions.

The main limitations of this research lie in the fact that we relied exclusively on Web of Science as a literature source. Although this database is reputable, it is important to note that there are other relevant sources, such as Scopus, Google Scholar, and many others, that should be considered for potential future research. This would expand the research scope and provide a better understanding of all relevant works related to the application of artificial intelligence in managing risks in software projects.

Additionally, one of the prospective directions for future research includes a detailed examination of specific artificial intelligence tools that can be used in managing risks in software projects. Furthermore, investigating the possibilities of integrating these tools

with existing agile methodologies widely accepted in software project management could yield significant insights into optimizing risk management processes in this context.

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REZIME

UPRAVLJANJE RIZICIMA U SOFTVERSKIM PROJEKTIMA PRIMENOM ALATA VEŠTAČKE INTELIGENCIJE

U proteklim godinama, zabeležen je značajan porast interesovanja za inkorporaciju veštačke inteligencije u oblast softverskog inženjeringa. Razlog za to leži u činjenici da je veštačka inteligencija postala sveprisutna i sve dostupnija, čime se efikasno primenjuje u različitim ključnim segmentima softverskih sistema. Njen doprinos se ogleda ne samo u stvaranju novih funkcionalnosti, već i u podršci postojećim procesima na softverskim projektima što često rezultira znatno unapređenim prilagođavanjem specifičnim zahtevima korisnika. Kroz ovaj rad dat je osvrt na primenu alata veštačke inteligencije u okvirima jedne od vitalnih oblasti upravljanja softverskim projektima – upravljanje rizicima. Kako bi se ovo postiglo sprovedena je bibliometrijska analiza literature koja se odnosi na upravljanje rizicima na softverskim projektima uz primenu alata veštačke inteligencije. Cilj ove studije je identifikacija i analiza ključnih trendova, autora, časopisa i ključnih reči u ovom multidisciplinarnom polju, kako bi se bolje razumeo napredak i relevantnost istraživanja na temu upravljanja rizicima na softverskim projektima primenom alata veštačke inteligencije. Metodologija uključuje pregled relevantnih baza podataka i identifikaciju relevantnih radova koristeći ključne termine povezane sa softverskim projektima, upravljanjem rizicima i veštačkom inteligencijom. Analiziraju se kvantitativni parametri kao što su broj objavljenih radova, autorska saradnja, citiranost i distribucija članaka po godinama i časopisima.

Ključne reči: *softverski projekti, rizik, upravljenje rizikom, veštačka inteligencija, Web of Science, bibliometrijska analiza*