The Evolution of the Rapid Application Development (RAD) Concept in Todays Digital Transformation

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***Abstract*— The Rapid Application Development (RAD) methodology was invented to meet rapidly changing business needs by emphasizing rapid prototyping and iterative feedback over extensive up-front planning. However, to meet the strong market demand for RAD skills, Higher Education (HE) institutions need to develop and make available training courses to a wide range of potential students in all EU countries, including those from non-IT backgrounds. This paper focuses on the RAD concept evolution analysis based on bibliometric analysis of scientific publications and this concept incorporation into HE courses to faster and cheaper way of digital transformation. The obtained results show that RAD processes evolve without influencing essential SE processes. However, we observed that their sub-processes and activities change in actual RAD processes depending on the main business goal.**

Keywords—rapid application development, RAD, digital transformation, low code, software engineering.

I. Introduction

The needs of today's business are changing as fast as the business itself. Therefore, the application systems that support such a business must be developed quickly and with the ability to adapt to changes. In this context, the concept of *digital transformation* has emerged to describe the changes that the adoption and implementation of digital technologies are having on society, industry and business [1]. Author G. Vial [2] define digital transformation "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies*". Low-code development platforms provide the technology mechanisms to facilitate and automate the development of software applications to support current business needs and drive digital transformation [3]. Organisations are adopting low-code development to drive digital transformation and increase responsiveness and customer focus, while addressing the shortage of software developers [4]. Authors [5] found that in particular cases the low-code approach could deliver a high quality and functional application with an impressive reduction in time and implementation complexity. Nevertheless, for such process we need appropriate methodologies, tools and skilled specialists [1] to implement it.

Therefore, for better understanding and development of a digital transformation, this paper briefly reviews the main concepts related to rapid application development (RAD), such as low-code, rapid prototyping, iterative development, fast-track development, etc., applying bibliometric analysis of scientific publications.

Also, this paper analyses the concept of a digital transformation in the scope and emphasizing the implementation of the EU Erasmus+ project "Embracing rapid application development (RAD) skills opportunity as a catalyst for employability and innovation" (RAD-Skills) at five European universities (Vilnius Gediminas Technical University (VILNIUS TECH), Tallinn University of Technology (TalTech), Riga Technical University (RTU), Technological University Dublin (TU Dublin), and University of Rijeka (UNIRI)) through 2022–2024. The aim of the project is to stimulate innovative learning and teaching practices, support digital and green capabilities of the HE sector, and to improve digital readiness, resilience and capacity of future generations for emerging advanced digital technologies, such as Low-code platforms (LCDP) and RAD. The actions of the project directly address high-quality education and training of ICT professionals to respond to the challenges posed by the constantly evolving market of digital technologies.

The rest of the paper is organized as follows. Section 2 is dedicated to related work, Section 3 discusses the bibliometric analysis performed. Section 4 answers the research questions, and in Sect. 5, discussion is presented. Sect. 6 draws conclusions.

II. Related Works

A. *Overview of Rapid Application Development (RAD)*

Rapid application development (RAD) is a software systems development methodology which applied to produce a high-quality system [6] and address software development challenges, offering faster delivery times and increased productivity [7]. The RAD model is characterized by its focus on user involvement, iterative development, and the use of reusable components [8]. This approach is particularly beneficial in environments where requirements are expected to change or evolve, as it allows for flexibility and adaptability in the development cycle.

The phases of the RAD process can vary slightly depending on the specific implementation, but generally, they include several key phases that facilitate rapid and flexible development (see Fig. 1).

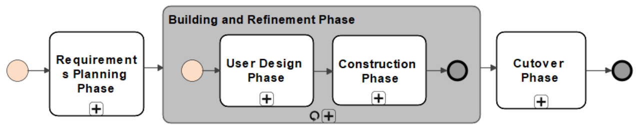

Fig. 1. Phases of the RAD process

Based on several reviews of RAD process [6, 9-11] these phases (see Fig. 1) are explained with highlights essential aspects of each phase:

a) Requirements Planning. This initial stage involves gathering and understanding the requirements for the system. This phase is characterised by collaboration between developers and stakeholders to ensure that the application meets user needs and business objectives. This stage is a critical component of the RAD process, ensuring that software development is aligned with future user benefits and existing business process constraints.

b) User Design. This stage involves the creation of prototypes and models of the system. It is a collaborative phase where users interact with developers to refine the system design through iterative feedback. This phase is essential for visualising the system for users and making necessary changes before developing a full-scale application.

c) Construction. This phase is the actual development of the application. It involves the programming and integration of the system components based on the prototypes and models developed in the previous phase. The construction phase is characterised by fast and short development cycles, allowing for quick adjustments and refinements based on user feedback.

d) Cutover. Also known as implementation, this final phase involves the deployment of the system in a business environment. It includes final testing and user training. This phase is critical to ensure that the system is ready for use.

Some variations of the RAD process include additional phases such as business modelling, process modelling and data modelling [12,13] These phases are integrated into the design and construction phases to ensure that the system is aligned with business processes and data requirements.

III. Methodology of Bibliometic Analaysis

A bibliometric analysis on the rapid application development (RAD) in Computer Science is conducted as proposed in [14]. Its general schema is presented in Fig. 2.

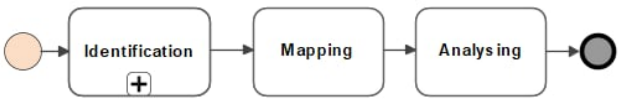

Fig. 2. The general schema for bibliometic analysis

A. Identification

In this step, the following activities are performed:

a) *Research Questions*. The main research question (MRQ) follows: What is the intellectual structure of RAD in Computer Science? According to MRQ, the following research questions (RQ) are defined:

RQ-1: What is the period covered by RAD?

RQ-2: What is the distribution of scientifical papers about RAD among the Web of Science categories?

RQ-3: Which countries are considering the use of RAD?

RQ-4: What are the main topics being studied in RAD?

b) *The List of Search Sources*. The Web of Science (WoS) digital database was used based on the experience reported in [15] and it is suitable for conducting this bibliometric analysis.

c) *Searching Query*. The key terms are identified and the final query is developed based on the WoS search requirements as follows:

("rapid application develop"* ***OR*** *"rapid prototyping"* ***OR*** *"iterative develop*"* ***OR*** *"fast track develop*"* ***OR*** *"low-code develop*"* ***OR*** *"accelerated develop*"* ***OR*** *"speedy application creation"* ***OR*** *"quick app develop*"* ***OR*** *"incremental develop*")*

d) *Searching by Query*. The search was performed using the defined search query with the following restrictions (see Table I).

TABLE I. RESULTS OF IDENTIFICATION STEP

Data base	*WoS Category*	*Document Type*	*Language*	*Search Result*
WoS	*computer science software engineering* **OR** *computer science theory methods* **OR** *computer science information systems* **OR** *computer science artificial intelligence* **OR** *computer science interdisciplinary applications* **OR** *computer science hardware architecture* **OR** *computer science cybernetics*	*article* **OR** *proceedings paper* **OR** *review*	English	5 045

B. Mapping

A set of relevant papers obtained was transferred to VOSviewer (https://www.vosviewer.com/), a software tool for conducting and visualising bibliometric networks [16]. The author keywords of the relevant papers were used to develop a keyword map on RAD. VOSviewer uses an automatic keyword identification technique [17]. It generates the map according to the closeness and strength of existing links between the keywords found, calculating the number of papers in which they occur together. The size of the bubbles represents the occurrence of the keywords. Furthermore, in this bibliometric analysis we focus on the colouring of the keyword map according to the Average Publication Year (APY), which indicates the average publication year of the papers in which a keyword occurs [18]. Note that APY is a positive rational number.

C. Analysis

In this bibliometric analysis the content was analysed as follows: 1) chronological visualisation and analysis (RQ-1); 2) visualisation and analysis (RQ-2); 3) visualisation of keyword occurrence based on APY and analysis (RQ-3); 4) visualisation and analysis of countries (RQ-4).

The found keywords were analysed quantitatively according to their APY (RQ-3) as follows: newest keywords – the frequency of these keywords is not high (i.e., in the context of this bibliometric analysis, but their APY is new (Fig. 5); continuous occurrence of keywords – the frequency of these keywords is medium or high, and their APY is medium (Fig. 5); and older keywords – the occurrence of these keywords can be different and their APY is old (Fig. 5).

IV. Main Results of RAD

The time period of the publications found on RAD (RQ-1) is shown in Fig. 3. The papers found were published between 1990 and 2024 (September). The trend line shows the waiving increasing number of publications on the analysed topic.

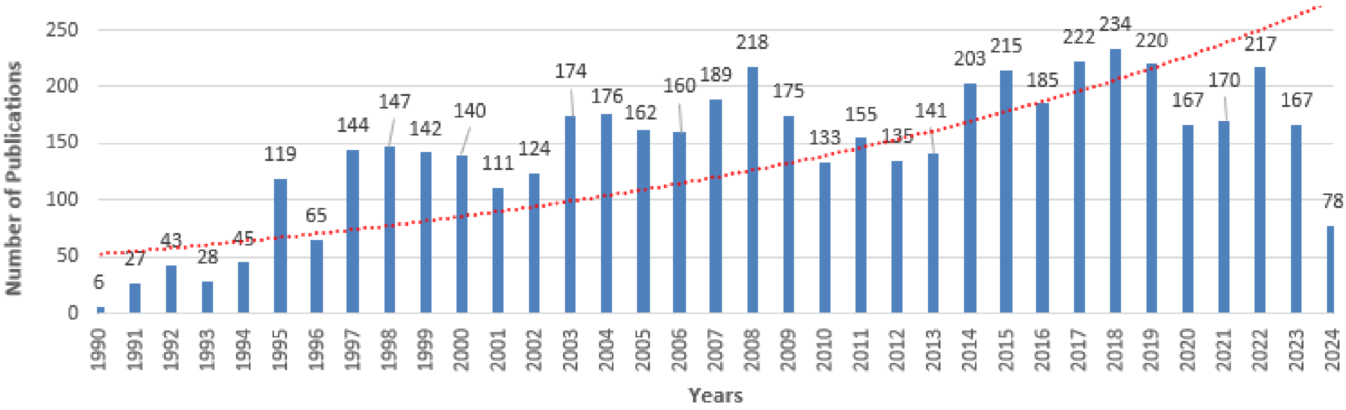

Fig. 3. The period of the found publications on RAD (RQ-1)

The distribution of the analysed topic by WoS categories (RQ-2) is shown in Fig. 4. As can be see, the most of publications are found in Computer Science Information Systems category (875 publications), Computers Science Artificial Intelligence (622 publications), Computer Science Theory Methods (602 publications). This is explainable because the RAD philosophy and phases are suitable and applicable in application development Information System and AI processes are integrated in the application development. Fewest publications found were found in Computer Science Cybernetics category of WoS (79 publications) and suggesting less research activity in this field concerning the topic's RAD. This is understandable because Cybernetics is a continued research process.

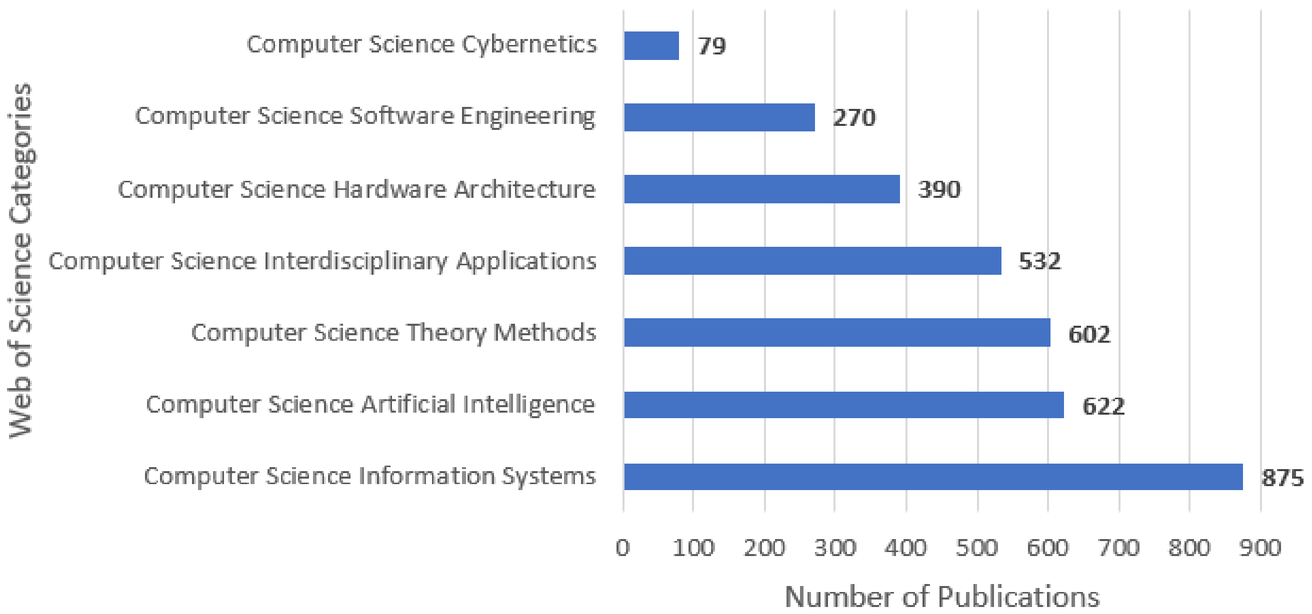

Fig. 4. The distribution of the scientifical publications on RAD among WoS categories (RQ-2)

The distribution of the analysed topic by country (RQ-3) is shown in Fig. 5. The x-axis shows the number of publications, and the y-axis lists countries in descending order of publications. As can be seen, the five most active countries, which perform analysis of RAD are USA, Germany, People's Republic of China, England and Canada. There is significant variation between countries, and it is directly related to the count of researchers.

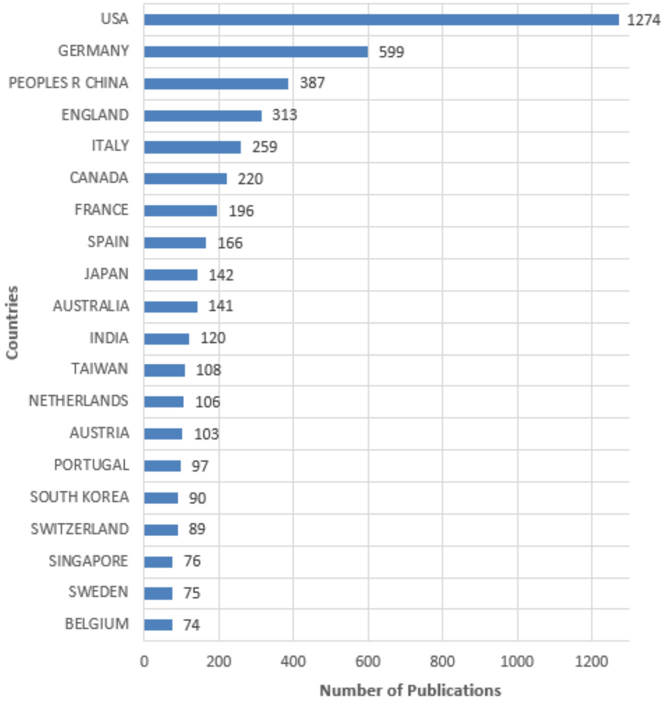

Fig. 5. Countries analyzing RAD (RQ-3)

The developed author keyword map, which represents the main topics investigated in RAD (RQ-4) according to (APY), is shown in Fig. 6. It is coloured as follows.

Keywords coloured in yellow are found in articles published in recent years (APY ~ 2021); green – APY ~ 2016; blue – APY ~ 2010 (see Fig. 6). The larger bubbles represent the more common keywords (i.e., design, model, algorithm), and the smaller bubbles represent the less common keywords (i.e., classification, MatLab, rad-hard), which, depending on their colour, may represent trends or unexplored (i.e., IoT, deep learning, mobile robot) and forgotten (i.e., associative algebra, database) topics. Yellow bubbles represent new keywords, i.e., their APY is equal to the current years, which means novelty and latest trends. They are as follows: IoT, robot, mobile robot, deep learning. Green and large bubbles represent keywords that occur continuously throughout the analysed period, i.e., information system, cloud computing, algorithm. Green and small bubbles show keywords that appear between 2014 and 2016, i.e., network, genetic algorithm, management.

For example, the authors of [19] presented an example of the application of a low-code paradigm for an open, multi-sided low-code framework that allows us to manage the entire network of a collaborative manufacturing and logistics environment that enables people, applications and Internet of Things (IoT) devices. The authors of [20] presented a RAD-based method for developing an agricultural irrigation system based on the Internet of Things (IoT). In [21] authors analysed benefits and limitations of using low-code development to support digitalization in the construction industry. Authors of [22] developed the Smart City Operational Platform Ecology (SCOPE) to address the growing demands, and incorporates machine learning, cognitive correlates, ecosystem management, and security.

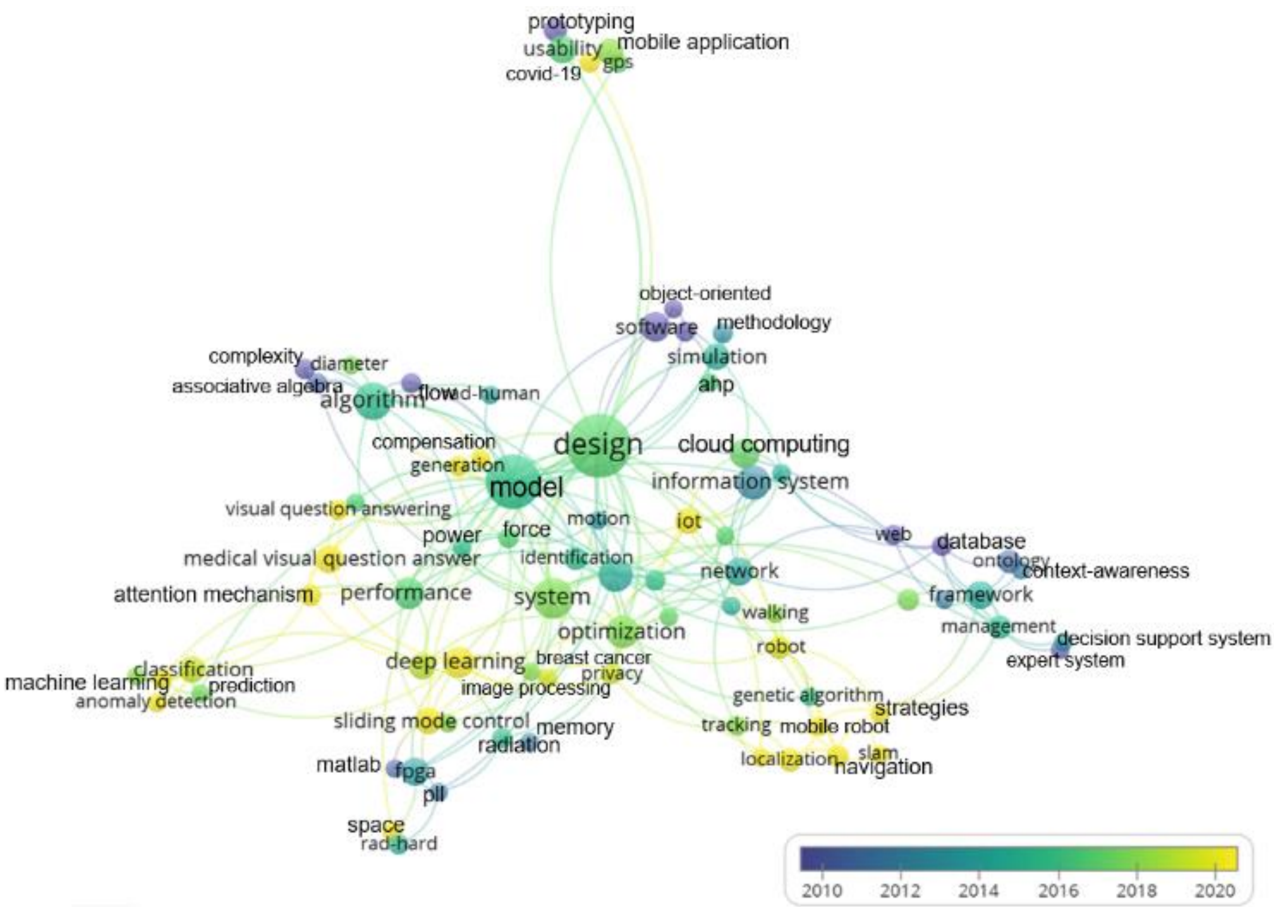

Fig. 6. The period of the found publications on RAD (RQ-1)

The newest yellow-coloured keywords with APY > 2019 are: deep learning, GPS, sliding mode control, privacy, IOT, robots, mobile robots, etc. The oldest blue-coloured keywords are: object-oriented, software, methodology, decision support system, expert system, information system, complexity, prototyping, web, database, ontology, etc.

V. DISCUSSION

In this research, we used bibliometric analysis to answer the main research questions: (MRQ) What is the intellectual structure of RAD in Computer Science? This MRQ was broken down into the following sub-questions: (RQ-1) What is the period covered by RAD? (RQ-2) What is the distribution of scientifical papers about RAD among the Web of Science categories? (RQ-3) Which countries are considering the use of RAD? (RQ-4) What are the main topics being studied in RAD?

The bibliometric analysis carried out on the topic of RAD shows a waiving increase in the number of papers, in the period between 1990 and 2024 (until September, 2024) (RQ-1). This can be explained by the development of RAD and its application in the analysed topic.

The analysis of distribution of scientifical papers among the Web of Science categories shows that the most active research on RAD topic is performed in Computer Science Information Systems category.

The analysis of countries investigating RAD (RQ-3) shows that the five most active and influential countries are as follows: USA, Germany, People's Republic of China, England and Canada.

To answer RQ-4, the mapping was done with VOSviewer and the keyword map based on occurrence and APY was developed. It shows that the newly appearing keywords in the field of RAD are: deep learning, GPS, sliding mode control, privacy, IoT, robot, mobile robot. However, the application of those approaches is not deep and mature enough in the analysed topic. This situation can be explained by the novelty of the application of RAD in computer science.

Summing up, RAD has a short time of application in the field of Computer Science. As stated by authors [5] further research is needed to better understand the strengths and weaknesses of each RAD and low-code approach, and to develop guidelines for choosing the most appropriate method for different types of applications. Therefore, more research is needed.

VI. CONCLUSIONS

The paper highlights the evolution of the Rapid Application Development (RAD) methodology, emphasizing its role in meeting rapidly changing business needs through rapid prototyping and iterative feedback. On the other hand, we observe that RAD has a relatively short application history in the field of Computer Science, which suggests that there is still much to learn and explore about its full potential and limitations.

The bibliometric analysis conducted in the research indicates a significant increase in the number of publications on RAD from 1990 to 2024, reflecting the growing interest and application of RAD in various fields. The research identifies the topics of RAD within Computer Science, revealing that the most common topics include design, model, and algorithm, while newer topics such as deep learning, IoT, and mobile robots are emerging but not yet deeply explored. The study finds that while RAD processes continue to evolve, they do not significantly alter essential software engineering processes. However, the sub-processes and activities within RAD can change depending on the main business goals, indicating flexibility in its application.

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REFERENCES

[1] T. Robal, U. Reinsalu, J. Leoste, L. Jürimägi, & R. Heinsar. Teaching Rapid Application Development Skills for Digitalisation Challenges. *In International Baltic Conference on Digital Business and Intelligent Systems*, 2024, June, pp. 177-192. Cham: Springer Nature Switzerland.

[2] G. Vial. Understanding digital transformation: A review and a research agenda. *Managing digital transformation*, 2021, 13-66.

[3] R. Sanchis, Ó. García-Perales, F. Fraile & R. Poler. Low-code as enabler of digital transformation in manufacturing industry. *Applied Sciences*, 2019 *10*(1), 12.

[4] A. Novales & R. Mancha. Fueling digital transformation with citizen developers and low-code development. *MIS Quarterly Executive*, 2023, *22*(3), 6.

[5] D. Aveiro, V. Freitas, E. Cunha, F. Quintal & Y. Almeida. Traditional vs. low-code development: comparing needed effort and system complexity in the NexusBRaNT experiment. *In 2023 IEEE 25th Conference on Business Informatics*, 2023, June, pp. 1-10, IEEE

[6] J. Martin. Rapid application development. Macmillan Publishing Co., 1991. Inc..

[7] R. Agarwal, J. Prasad, M. Tanniru, J. Lynch.. Risks of rapid application development. *Communications of the ACM*, 2020 43(11es), 1-es.

[8] P. Beynon - Davies, H. Mackay, D. Tudhope, D. ‘It’ s lots of bits of paper and ticks and post - it notes and things...”: a case study of a rapid application development project. 2020, *Information Systems Journal*, 10(3), 195-216.

[9] P.Beynon-Davies, C. Carne, H. Mackay & D. Tudhope. (1999). Rapid application development (RAD): an empirical review. *European Journal of Information Systems*, 1999, 8(3), 211-22

[10] P. Beynon-Davies & S. Holmes, S. Design breakdowns, scenarios and rapid application development. *Information and software technology*, 2002, 44(10), 579-592.

[11] H. Berger, & P. Beynon-Davies. The utility of rapid application development in large-scale, complex projects. *Information Systems Journal*, 2009, 19(6), 549-570.

[12] B.P. Kumar, & Y. Prashanth. Improving the rapid application development process model. In 2014 *Conference on IT in Business, Industry and Government*, 2014, March, pp. 1-3, IEEE

[13] M.A. Fauzi, H. Tribiakto, A. Moniva, F. Amir, I.K. Ilyas & E. Utami. Systematic Literature Reviews on Rapid Application Development Information System. *Bulletin of Computer Science and Electrical Engineering*, 2023, 4(1), 57-64.

[14] K. Petersen, S. Vakkalanka, L. Kuzniarz. Guidelines for conducting systematic mapping studies in software engineering: An update. *Information and software technology*, 2015, 64, 1-18.

[15] D. Kalibatiene and J. Miliauskait , "A Hybrid Systematic Review Approach on Complexity Issues in Data-Driven Fuzzy Inference Systems Development. 2021, 32, 1–34, *Informatica*, vol. 32, pp. 1-34, 2021

[16] N. Van Eck, L. Waltman, E. Noyons and R. Buter. Automatic term identification for bibliometric mapping. *Scientometrics*, vol. 82, p. 581–596, 2010

[17] G. Khalil and C. Gotway Crawford. A bibliometric analysis of US-based research on the behavioral risk factor surveillance system. *American journal of preventive medicine*, 2015, 48(1), 50-57.

[18] N. Van Eck and L. Waltman. Manual for VOS Viewer Version 1.6.10, CWTS, 2019.

[19] R. Sanchis, O. García-Perales, F. Fraile, R. Poler.. Low-code as enabler of digital transformation in manufacturing industry. *Applied Sciences*, 2019, 10(1), 12.

[20] A.K. Nalendra. Rapid Application Development (RAD) model method for creating an agricultural irrigation system based on internet of things. *In IOP Conference Series: Materials Science and Engineering*. 2021 March, Vol. 1098, No. 2, p. 022103, IOP Publishing.

[21] E. Martinez, L.Pfister. Benefits and limitations of using low-code development to support digitalization in the construction industry. *Automation in Construction*, 2023, 152, 104909.

[22] Q. Abbas, G. Ahmad, T. Alyas, T. Alghamdi, Y. Alsaawy, & A. Alzahrani. Revolutionizing Urban Mobility: IoT-Enhanced Autonomous Parking Solutions with Transfer Learning for Smart Cities. *Sensors*, 2023, 23(21), 8753.