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Ismail Kocayusufoğlu
Editor-in-Chief

Dear Readers,

It is with great pleasure that I welcome you to the November 2024 issue of the **CIT Review Journal (CRJ)**. As the Rector of the Canadian Institute of Technology and the Editor-in-Chief for this edition, I am honored to introduce a diverse range of insightful research contributions that reflect the growing impact of innovative ideas and solutions across various academic fields.

In this issue, we are proud to present a collection of papers that address critical challenges and offer pioneering approaches in education, technology, economics, and social science.

I would like to extend my sincere thanks to all the contributors, peer reviewers, and the editorial team for their dedication and hard work in bringing this issue to life. Each of these papers offers valuable contributions to their respective fields and exemplifies the spirit of collaboration, innovation, and academic excellence that we strive to foster at CIT and within the broader academic community.

We invite you to explore the diverse content of this issue and hope it will spark new ideas and further research in your respective fields. Thank you for being part of our community, and as always, we welcome your feedback and look forward to continuing this journey of exploration and knowledge sharing together.

Warm regards,

Prof. Dr. Ismail Kocayusufoğlu
Rector
Editor-in-Chief

ENHANCING EDUCATION THROUGH THE PARTNERSHIP BETWEEN VOCATIONAL SCHOOLS, UNIVERSITIES, AND NGOS IN ALBANIA

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Abstract

This research explores the cooperation model between Vocational Schools, Universities, and NGOs in Albania, focusing on the benefits, contributions, and challenges each party faces. The study involved the distribution of a questionnaire to participants from the main stakeholders. The findings suggest that collaboration between these entities can lead to improved curricula, enhanced student readiness for the labor market, and the development of innovative teaching methods. The research also identifies key factors for successful collaboration, such as selecting appropriate actors, dedicating time to establish partnerships, and providing necessary support and incentives. The study concludes that understanding the time required for collaboration and effective organization are crucial elements in maximizing the success of collaborative ventures in research and development. Looking ahead, the authors propose adapting successful cooperation models from Europe to the context of Albania to promote innovation and strengthen the country's education system. Comments from participants indicate strong support for the continuation and expansion of this cooperation model to benefit all parties involved.

Keywords: Cooperation, Vocational Schools, Universities, NGOs, benefits, contributions, challenges, education system.

1. LITERATURE REVIEW

In recent years, the importance of collaboration between academia and society in knowledge production has become increasingly recognized in government research policy. This shift has been noted by scholars such as Fenwick & Farrell, Jonsson et al., and Skoglund, who have argued for closer interaction between researchers and practitioners. Groundwater-Smith goes further to suggest that governments are now turning to practitioner inquiry as a means to address pressing questions and issues.

While collaboration at the practitioners' level, involving researchers and teachers, has received considerable attention in educational research, there remains a gap in understanding how universities organize collaboration with schools at the organizational level. This article seeks to fill this gap by examining how universities engage in collaborative efforts as part of their operations.

Drawing on the insights of Levin and Cooper, who stress the importance of studying organizational processes and structures, the focus is on how universities establish and maintain collaborations with schools.

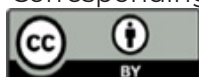
Despite a growing body of literature on practitioner research and university partnerships, there has been limited research on the specific role of universities in collaborating with schools. By taking an organizational perspective, this article aims to provide a deeper

understanding of the structures and practices employed by universities in this collaborative endeavor. Baumfield and Butterworth have also highlighted the lack of research on university-school collaboration, underscoring the need for further investigation into this dynamic relationship. By shedding light on the challenges and opportunities inherent in collaborations between these two distinct educational organizations, this study aims to offer valuable insights into the complexities of such partnerships and contribute to a broader understanding of the collaborative landscape in education.

As outlined in the introduction, there is a growing interest in enhancing collaboration between universities and high schools to engage in activities that support research and development. Partnership is seen as a positive concept in current discourse, although it is often taken for granted and not critically examined. Existing literature on collaboration is limited and mostly consists of intervention studies and evaluations of development projects (Prøitz et al.). Some key factors have been identified as crucial for successful collaboration, particularly in the context of organizing for collaboration.

One essential factor highlighted in previous research is the importance of dedicating enough time to establish long-term partnerships that benefit all involved organizations. Studies on "research-practice

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partnerships" (RPP) (Coburn & Penuel; Coburn et al.; Cooper et al.; Henrick et al.) have emphasized the need for extended periods of collaboration to address persistent challenges in practice. These partnerships are characterized by a shared goal that requires time to develop effectively. The time dimension in partnerships allows for the exploration of complex issues and the resolution of challenges rooted in institutional and organizational structures. By focusing on practical problems, these partnerships aim to be relevant for schools and address pressing issues encountered in practice (Prøitz et al.).

Mörndal argues that while there are numerous definitions of collaboration, a common thread is the collaboration of organizations with diverse backgrounds working towards common objectives. Understanding the concept of collaboration involves recognizing the time required for parties to work together and the long-term benefits that can result (Mörndal). Despite differing goals and missions, organizations can find common ground in the advantages of collaborative efforts. Jonsson et al. emphasize the importance of discussing and aligning different actors' understandings and perspectives on knowledge to maximize the benefits of collaboration. Time is a critical factor in enabling participants to establish relationships, identify shared interests, and build trust in collaborative endeavors.

This part of the literature review discusses the increasing emphasis on collaboration between universities and schools for research and development activities. While collaboration is considered positive, the existing literature on the subject is limited and mainly focuses on intervention studies and evaluations of development projects. One key factor identified for successful collaboration is the importance of dedicating enough time to establish long-term partnerships that benefit all organizations involved. Research-practice partnerships, in particular, highlight the need for extended periods of collaboration to address persistent challenges in practice effectively. The concept of collaboration involves organizations with diverse backgrounds working towards common objectives. Despite differing goals and missions, collaborating parties can find common ground in the benefits of working together. Establishing relationships, identifying shared interests, and building trust are crucial aspects of successful collaborative efforts.

In conclusion, understanding the time required for collaboration and the long-term benefits it can bring is essential for maximizing the success of collaborative ventures in research and development. Time allows for the exploration of complex issues, alignment of different perspectives, and the establishment of trust among participants, ultimately leading to more effective and impactful collaborative efforts.

Secondly, carefully selecting actors based on their roles within their organizations is crucial for successful collaboration. The individuals involved in schools or universities have a significant impact on the outcomes of research and development projects. Previous research has often treated educators as a

homogeneous group, but it is essential to consider the different perspectives of teachers, school leaders, district policymakers, and central office staff when determining relevance (Honig; Spillane). Each professional group has specialized knowledge and expertise in their own area of work. Identifying internal challenges, from the central office to teachers in the classroom, is also crucial for successful projects (Honig). The selection of actors is key in determining the focus of research and development areas and ultimately influences the results that can be achieved. Thirdly, the internal organization of universities is a critical factor in collaboration outcomes from the perspective of university representatives. In addition to teaching and research, universities have a legal obligation to collaborate with the community (SFS; Öhman Sandberg). To promote collaboration, incentives for researchers are necessary; however, the current reward system may discourage collaboration by prioritizing publications in prestigious journals over practical texts for educators (Burkhardt & Schoenfeld). Scholars may be hesitant to engage in collaborations with school representatives who have different goals. Therefore, providing structures that meet the needs of researchers at universities is essential for facilitating successful collaborative efforts.

Carefully selecting the right actors for collaboration within organizations is crucial for achieving successful outcomes. It is important to consider the diverse perspectives and specialized knowledge of educators, school leaders, policymakers, and central office staff when determining relevance for research and development projects. Each professional group brings unique expertise to the table, and understanding internal challenges at every level is essential for project success.

Universities play a crucial role in collaboration, with a legal obligation to engage with the community. Incentives for researchers are important for promoting collaboration, but the current reward system may not always align with the goals of collaborative projects. Creating structures that meet the needs of university researchers is essential for facilitating successful collaborations with schools and other organizations.

Overall, for the second and third part of the above literature review, the selection of actors within organizations and universities is key in determining the focus of research and development areas, as well as influencing the results that can be achieved through collaborative efforts. By carefully selecting the right mix of individuals and providing the necessary support and incentives, organizations can enhance their collaborative endeavors and drive impactful outcomes.

In summary of the literature review, the way work is structured can greatly influence the success of collaborations with schools. A well-organized structure provides opportunities for sustained collaboration towards shared objectives. It is essential for participants in these collaborations to possess expertise in the relevant field of work, and for there to be internal motivations for collaboration within the organizations involved. Additionally, factors such as the

focus of research and the dissemination of results can also impact the activities undertaken in collaborations (Burkhardt & Schoenfeld; Levinson). While these aspects are beyond the scope of this article, which focuses on the organization of this cooperation, we rely on the framework of the partial organization (Ahrne & Brunsson) to analyze how the organization impacts collaboration. This analytical approach will be further detailed in the following sections after introducing the collected material.

2. METHODOLOGY

In this research, the authors have gathered the material and re-analyzed the results. In the next section, we discuss research findings from this collaboration. Following, the theoretical and methodological framework is presented. In the framework of drafting this paper, a questionnaire consisting of 12 questions for participants from the stakeholder organizations. The main objective was to research the model of cooperation between Vocational Schools, Universities, and NGOs. The completion of these questionnaires clarified the perspectives, viewpoints, and opinions of the actors involved in this cooperation model. The questionnaire was distributed online and in hardcopy, during February-March 2024 to a random population of these three segments.

3. DATA ANALYSIS

1-Analysis of Section A: Demography

The questionnaire consists of three sections, namely: 1. General data; 2. On the tripartite model of cooperation; and 3. Partners' Cooperation.

Questionnaire data show that 28.3% of respondents are female and 71.7% of respondents are male.

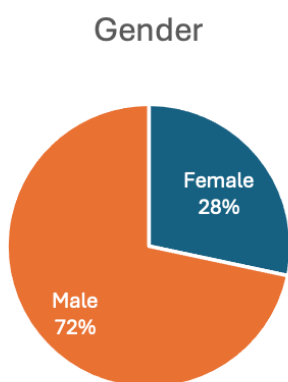


Fig.1

The respondents are representatives from VET School, ICLA as a non-governmental organization and Albanian University. The categories of respondents are lecturer, student, teacher, student, NGO representative, donor, etc. representing the respective institution. More specifically, the highest number of questionnaires was completed by VET students, 25% or 15 respondents, followed by university students

23.3% or 14 respondents, then lecturers with 21.7% or 13 respondents, teachers 18.3% or 11 respondents, and only 1.7% or 1 donor respondent. Only 5% or 3 respondents expressed they do not know (Figure No. 3). The respondents who have chosen to share an opinion on why they consider this model innovative state that: "Collaborations always bring great achievements, it is considered as a connecting bridge for the exchange of ideas, methods and experiences, innovation in the development of professional education...etc".

Questionnaire participants

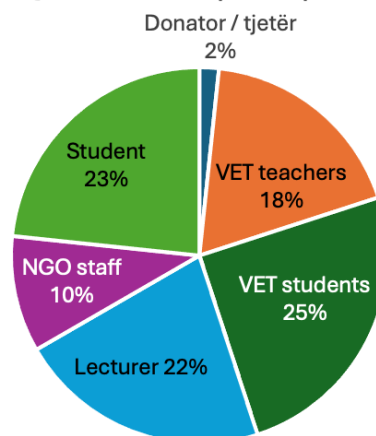


Fig.2

1-Analysis of Section B: "On the tripartite model of cooperation"

This section consists of 6 questions in total.

The data obtained from this section confirm the fact that this model has support and is considered an innovative model by the vast majority of respondents. More specifically, the analysis of question 01: Are you in favor of the cooperation of actors in the triangle: vocational school, university and NGO? The results show that 91.7% of the respondents are in favor of a collaboration between a professional school, university and NGO, 3.3% of the respondents said no and only 5% of them are expressed I don't know.

Are you in favor of the cooperation of actors in the triangle

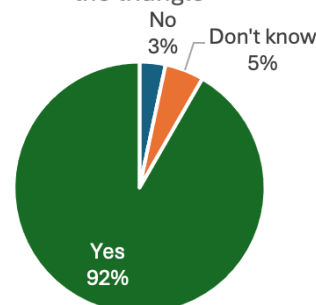


Fig.3

The data obtained from question 02 also show that the tripartite cooperation model: secondary school, vocational school, university and NGO is considered innovative by 95% of the respondents. Some of them emphasize that: "This cooperation model is an innovative approach that integrates theory, practice and the needs of the labor market to improve education and the development of students' competencies. This cooperation model seems to be a positive step towards increasing the quality of professional education in Albania"

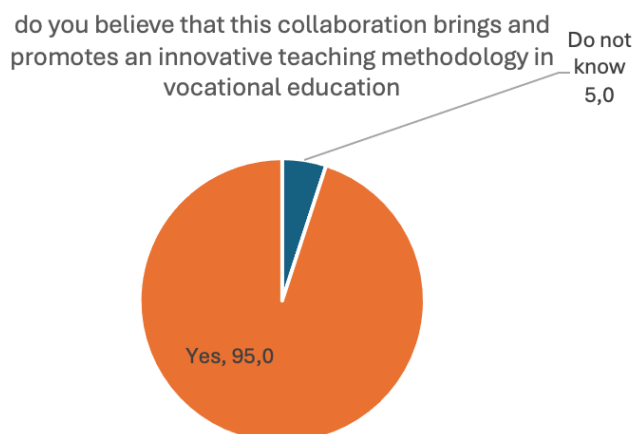


Fig.4

Question 03: Referring to this initiative, do you believe that this collaboration brings and promotes an innovative teaching methodology in vocational education? The data show that about 88.3% or 53 respondents answered "yes" that they believe that this cooperation brings and encourages an innovative teaching methodology in vocational education, while 8.3% or 5 of them said "I don't know" and only 3.3% or 2 of them expressed "no". These results confirm the continuity of the belief that this model of cooperation is an innovation and is considered as a driver of an innovative methodology in teaching in VET. Valuable comments come when respondents are asked for a comment on this question. Some believe that: "Through the sharing of experiences and successful practices between lecturers and teachers working in vocational education, this cooperation promotes new initiatives and innovation in teaching in vocational education through the exchange of experiences and familiarity with different methods." Universities offer a complementary methodological framework for VET and for the latter, applied knowledge". Some of the respondents think that: "Vocational school is a good springboard for gaining practical skills that favor the learning process during the university career" On the whole, the opinions of the respondents converge in the belief that this initiative of the implementation of a project with three actors that represent opportunities, interests, and different service categories have potential and encourage innovative alternatives in the teaching process.

Even question 04, which is related to the belief that "this cooperation brings and encourages an innovative methodology of improving the competencies of

students in education", the answers confirm the positive aspect and the belief that this cooperation brings and encourages an innovative methodology of improving the competencies of students. More specifically, about 85% or 51 of the respondents answered "yes", 11.7% or 7 of them said "I don't know" and only 3.3% or 2 of them said "no".

The same applies when analyzing the answers to question 05 when the respondents are asked: "If this form of cooperation is expected to affect the topics/ subjects taught in university". The continuity of perceptions remains and the positive belief about the impact of this cooperation is confirmed. The results are the same as in question 03 where about 88.3% or 53 of the respondents answered "yes" that they believe that this collaboration brings and promotes an innovative teaching methodology in vocational education, while 8.3% or 5 of them expressed "I don't know" and only 3.3% or 2 of them said "no". Some respondents think that this form of cooperation allows universities to better understand the education of students and the knowledge they need for the labor market.

Of interest are the perceptions obtained from the question "Do you think a policy is needed to structure long-term cooperation between schools of education and vocational training, universities and NGOs" where about 81.7% or 49 of the respondents answered "yes" who believe that a policy is needed to structure long-term cooperation between these three actors, while 15% or 9 of them said "I don't know" and only 3.3% or 2 of them said "no".

Most of the respondents believe that the cooperation should be long-term assuming the productivity of the initiative increases with time. Others believe that the time has come to create a model of long-term synergy between actors who have common goals. Legal forms or mechanisms must be found to create long-term cooperation. An interesting comment was the involvement of businesses and state institutions in this cooperation. More specifically, the respondents propose: "A four-helix approach, where the cooperation includes universities (and professional education), civil society as well as the private sector and state institutions.

Referring to this initiative, do you believe that this collaboration brings and promotes an innovative teaching methodology in vocational education?

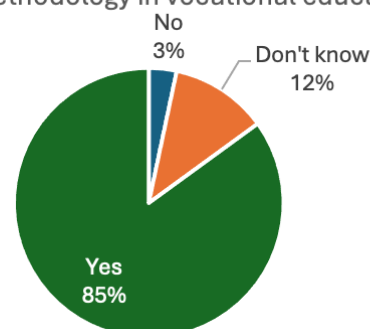


Fig.5

3-Analysis of Section C: "Cooperation and relations between partners"

Questions addressed in this section are profiled for each actor separately. The section is profiled with group questions for four categories: a) Representatives from the VET school; b) Albanian University; c) ICLA; e) Donor.

The purpose of this dedicated section is to analyze views on cooperation, benefits, challenges, and relationships from their perspective and role in this project.

C.1: Group-section of questions for representatives from the Professional School

Question 01: List three benefits that Vocational Training Schools can have from cooperation with universities and NGOs. The analysis of the response data shows that the three most important benefits identified by the respondents are:

1) Involvement in projects; 2) Exchange of experiences between the parties and 3) Teaching methods

It is worth mentioning that the respondents also value other benefits such as: Professional practice or encouraging young people for innovative entrepreneurship.

Question 02: List three contributions where Vocational Training Schools can contribute in cooperation with universities and NGOs. The answers of the respondents to a considerable extent converge as follows: 1) Collaborations in projects; 2) Improvement of curricula with a focus on the integration of innovative methodologies and 3. Promotion of this cooperation as a model of success.

In addition to the three above-mentioned contributions, there were also responses that evaluated the VET schools for the value and contribution they can give from a practical point of view on innovative technologies, professional practices and exchange of experiences.

Question 03: List three challenges that Vocational Training Schools may have from cooperation with universities and NGOs. The answers of the respondents to a considerable extent converge as follows: 1) The possibility to intervene in the curricular programs; 2) The approach of the teaching staff with the innovative model, financial impossibility for long-term cooperation; 3) Formulation and writing of projects.

Very valuable information was provided by the respondents when they were asked if you have any comments or thoughts that you would like to share with us on the future of this cooperation model.

The majority of respondents agree that it is a very good cooperation, necessary and that this model of cooperation should continue for a long time.

C.2: Group section of questions for University representatives

This set of sections consists of the same questions but with a focus on the perspective of representatives and collaborators in the project coming from the University.

Question 01. List three benefits that universities can have from cooperation with Vocational Training Schools and NGOs: A valuable point of view comes from the answers of the respondents who emphasize that the benefits are as follows: 1) Exchange of experiences - the combination of theoretical knowledge from universities with practical skills from technical schools enriches the learning experiences of students and can help the university to create new branches and adapt the curricula according to the needs of the labor market; 2) Cooperation in projects; 3) New ideas from this cooperation model that can be used by the university.

Also, a part of the respondents estimate that the benefits come from joint efforts to ensure that the curricula match the needs of the private and public sectors, increasing the readiness of students for the labor market through tailored programs. Some think that this model of cooperation brings benefits in the context of the opportunities to develop the scientific research of the students, considering the practices they have developed during their professional education.

Question 02: List three contributions where universities can contribute to cooperation with Vocational Training Schools and NGOs. Most respondents' answers value the following as valuable contributions: 1) Professional support, and curricular development: Universities can contribute by designing and refining curricula to incorporate theoretical foundations and interdisciplinary perspectives, ensuring that programs meet academic standards and the requirements of industry. 2) Involvement in Projects 3) Universities bring extended knowledge and teaching experience to collaborative efforts, enriching educational experiences for students and providing mentorship in research and professional development.

Question 03. List three challenges that universities may have from cooperation with Vocational Training Schools and NGOs. The respondents have assessed the three main challenges as: 1) Intermingling of interests, coordination, and bureaucratic and administrative obstacles. 2) Providing resources and financing for cooperation and long-term projects. 3) Linking theory with practice and commercialization of ideas.

Question 04. Do you have any comments or thoughts that you would like to share with us on the future of this cooperation model? The comments received are positive regarding this cooperation model. Specifically, some respondents think that the future of this cooperation is quite promising, especially at the threshold of rapidly developing technological advances

and the growing demand for skilled professionals in various industries. The respondents estimate that it is important to continue the institutional and financial support for this model, ensuring a wide involvement of actors and a sustainable approach to developments in the field of education and the labor market. For them, this model can serve as a good example for VET, the university, and for NGOs in improving education and preparing students for a successful future in the professional field.

C.3: Group-section of questions for NPO representatives and experts

Question 01. List three benefits that NGOs can have from cooperation with Vocational Training Schools and universities. The respondents consider the three main benefits of this cooperation: 1) Partnership, exchange of experiences, and innovative ideas between the parties that are part of this cooperation. 2) More innovation and research for new contemporary practices. 3) Necessary and suitable actors to bring together two links of the educational system by offering the experience, practice, and flexibility of action that they have.

Question 02. List three contributions where NGOs can contribute to cooperation with Vocational Training Schools and universities. Respondents estimate that the contribution of NGOs is related to: 1) Preparation of project proposals and coordination of actors. 2) Flexibility and lack of bureaucracy in the implementation of activities and 3) Policy advocacy and networking among partners.

Question 03. List three challenges that NGOs may have from cooperation with Vocational Training Schools and universities. The respondents estimate that the challenges that NGOs encounter in collaborations of this nature are related to: 1) Limited financial resources, finding funds to try collaborations of this nature remains a challenge. 2) Bureaucracy and human resources within educational institutions and 3) Formalization of a cooperation model since the sustainability of the staff and continuity of cooperation remains a challenge.

Question 04. Do you have any comments or thoughts that you would like to share with us on the future of this cooperation model?

Mostly, the respondents' comments assess that this is a collaboration that brings value to the work of each partner and that the success of this model depends a lot on its replication and the duration of the partnership. They suggest that it would be to the benefit of all parties if this type of cooperation becomes permanent to be followed by other educational institutions.

C.4: Group section of questions for the donor and other supporters of the initiative

From the donor's point of view, the benefits and contributions that can come from the cooperation of actors in the triangle: professional school, university, and NGO are: 1) More young people who have developed skills and competencies such as critical thinking, entrepreneurship and have been introduced to concepts of "what is innovation" 2) More teachers in vocational schools who have developed/ increased skills and competencies such as digital, have introduced and tested innovative teaching methodologies, etc. 3) In-depth partnership between the parties, something that has generated other ideas to continue the cooperation brought by Risi. A better understanding of the need to be dynamic, and always open to development and change to respond to market needs.

Following the implementation of the "Living Labs for Innovative Creators" project, the second questionnaire was carried out by the end of the project activities. The realization of this questionnaire at this stage of the project development helps in a comparative approach to the views and opinions of the participants involved in this cooperation model. The questionnaire was distributed in the online version and was completed by N=45 respondents.

Very valuable information was provided by the respondents when asked of any comments or thoughts to share on the future of this cooperation model. The best part of the respondents admit that this cooperation model is and will be successful for all parties, since each of them has designed the capacities in a different dimension, definitely with a positive aspect and with increasingly progressive development. The importance and role that ICLA has as a catalyst for the good functioning of this model is emphasized. Some of the respondents claim that "they hope that this model of cooperation will continue as many new initiatives of interest in tripartite development have been identified. The cooperation model has great potential to improve the quality of education and professional treatment.

CONCLUSION

In conclusion, the importance of collaboration between universities and schools for research and development activities could be increasingly recognized in government research policy. While existing literature on the subject is limited, key factors for successful collaboration have been identified, including the dedication of time for establishing long-term partnerships, the selection of appropriate actors within organizations, and the internal organization of universities to support collaborative efforts. By carefully selecting actors and providing necessary support and incentives, organizations can enhance their collaborative endeavors and drive impactful outcomes. The structure of work and internal motivations for collaboration also play essential roles in the success of such partnerships. Overall, understanding the time required for collaboration, selecting the right actors,

and organizing effectively are crucial elements in maximizing the success of collaborative ventures in research and development.

On the future of this cooperation model, it is emphasized that this approach may be new in Albania, but not so new / tested in Europe. In light of the aspiration to be part of the EU, the need for cooperation, to build alliances (even under the promotion of innovation) will become more and more important. The European Union is aiming to strengthen Europe's innovation capacity by fostering innovation through cooperation and knowledge transfer between higher education, vocational education (both initial and continuing), and the wider socio-economic environment, including research and society. civil. The proposal is: to look for cases of success in Europe and adapt the approach to the context of Albania, bringing innovative approaches and interpretations.

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EMPIRICAL EVIDENCE ON THE REAL MONEY DEMAND DETERMINANTS AND ITS STABILITY IN NORTH MACEDONIA

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Abstract

The aim of this study is to empirically examine the determinants that have influence on the real money demand and its stability in case of North Macedonia. The used data are analyzed quarterly, over the period 1997 (q1) to 2020 (q4). The research method consists of time series econometric techniques, using Cointegration analysis (Trace and the Maximum Eigenvalue statistics) for checking long and short - term and Vector Error Correction Method (VECM). The estimation results show that there is one Cointegration equations among the five variables. The ECTt-1 carries a negative sign which confirms the long-run relationship in the Cointegration analysis. The long-run coefficient indicate that all the selected variables have an impact on the real money demand. Specifically, interest rate on deposit in denar and exchange rate have a negative impact on the real money demand, while real industrial production and the increased consumer price index have a positive impact on the real money demand. The short-run results of our VECM model shows that the second lagged of real money demand, the second and the third lagged of real industrial production, the second and the third lagged of consumer price index had a significant impact on the current real money demand. Moreover, the results also show that the real money demand function had remained persistent stable throughout the analyzed period in case of North Macedonia, but again we must be cautious that the time series data used in our study is not that long.

Keywords: Real Money Demand, Cointegration analysis, Vector Error Correction Model, Determinants, Stability, North Macedonia.

JEL E41 Demand for Money

I. INTRODUCTION

North Macedonia economy faced challenges in the last year's due to economic growth and maintenance of macroeconomic balances. Additionally, negative developments in the global area are reflected in added uncertainties in the North Macedonian economy. Moreover, higher food, fuel and primary commodity prices are translated into stronger foreign inflationary pressures, expansion of trade deficit and potentially weaker domestic demand as a result of negative effects on North Macedonian households' financial balances.

Therefore, starting from this point monetary policy makers should be careful in implementing the current regimen of monetary targeting. The demand for money is one of the topical issues that have attracted the most attention in the literature, both in developed and developing countries. Sustainability of money demand is one of the essential factors on which it is based the choice of monetary regimen. The Central Bank's monetary policy and goals are often depending on its thoughtful and stability of money demand, a stable demand function of money means that the quantity of money is predictably related to a small set of key variables linking money to the real sector of the economy (Judd and Scadding, 1982).

However, when the demand for money is not stable (real and nominal interest rates will change) there will be economic fluctuations. North Macedonia as a small but yet open economy, has a relatively high degree of

euroization and in transition with partial euroization, the theory suggests that the real money demand is determined by: output, reflecting economic activity; the interest rate, as the opportunity cost of holding money; and the expected change of exchange rate, as the opportunity cost of holding domestic currency (Handa 2000), and hence it influences the euroization. Therefore, many empirical studies are dedicated to investigate what are the crucial determinants of the money demand function, and to observe if it is stable in long and short run. Most studies use gross domestic product, gross national disposable income, consumption expenditure and industrial production, as a proxy for output to measure the economic activity, and consumer prices as a conventional measure of prices in the economy, opportunity costs of holding money and many other variables.

Our empirical literature review focuses on Central and Southeast Europe (including Republic of North Macedonia as well) based on the reason, that it would be more useful in background of our research. More of these studies are country specific studies not panel studies. According to Skrabic and Plazibat (2009), real money demand function is analyzed within multivariate time-series framework, empirical results provide the evidence that real industrial production and exchange rate explains the most variations of money demand in the long-run, while interest rate is significant only in short-run. Golinelli and Rovelli

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(2002) analyzed the effect of interest rate used as the transmission mechanism tool on the inflation and money demand in the Czech Republic, Poland and Hungary, and measured the effect of interest rates in the real money demand and prices in the domestic market for the period 1991- 2000. The result provides that interest rates and exchange rate were found to be significant and the stability tests showed that the early stage of transition had been marked by the instable money demand while its stability would be achieved at a later stage.

Maravić and Palić (2005) analyze the long and short-term money demand in Serbia for the period January 1996 to March 2005, the Cointegration analysis shows that there is a strong Cointegration relationship between real money, overall economic activity, inflation and interest rate on deposits in denar. Short-term model (ECM) proved that the most important determinant of real money demand is inflation and exchange rate. The analysis has proved that the interest rate on deposits in denar, is statistically insignificant determinant and does not have significant role in money demand. The results of the empirical analysis suggest that the demand for money in the whole analyzed period is unstable. Kjosevski (2013) analyze the long and short-run determinants, and stability of money demand in case of the Republic of Macedonia using monthly data from January 2005 to October 2012. Empirical results provide the evidence that exchange rate and interest rate had impact on money demand in the long-run, while interest rate is significant only in short-run and the result also shows that money demand is stable.

III. EMPIRICAL RESULTS

Empirical results of the tests are presented in this section. Before proceeding to Cointegration analysis, as first we need to check the order of integration of the variables. In order to determine the order of integration, the Augmented Dickey-Fuller (ADF) is applied to the levels and the first differences. According to the results of Augmented Dickey-Fuller (ADF) test presented in

II. DATA AND METHODOLOGY APPROACH

In order to investigate the macro-determinants of money demand relationship in North Macedonia, we based on the model of Skrabic and Tomic - Plazibat (2009), and selected variables as following:

- ✓ Real money demand ($RM1 = M1/CPI$);
- ✓ Real industrial production adjusted with producer price index, as a proxy of real output (RIP);
- ✓ interest rate on deposits in denar (IRD);
- ✓ exchange rate of denar per euro (ER);
- ✓ consumer price index (CPI).

We used quarterly data from q1-1997 to q4-2020 according to the official reports of the National Bank of the Republic of North Macedonia. All the data are transformed into natural logarithms (denoted Ln), except the interest rate, which is defined as $[(1 + \text{interest rate}/100) * 100]^1$. The VECM approach provides a framework for the empirical investigation determinants that have influence on the real money demand and its stability. Namely, it enables an investigation of short- and long-run effects. The methodology proceeds through the following stages:

- first, testing each variable in the model for stationarity;
- second, specifying the VECM, which means determining the lag order of the underlying VAR, testing for Cointegration and the Cointegrating rank, and imposing restrictions on the Cointegrating vector(s) and short-run parameters in the model;
- third, checking the model by diagnostic tests;
- four, interpreting results from the estimated model.

Table 1, all the variables are non-stationary at levels but stationary in the first difference since the t-statistics are greater than the critical value of t-statistic at 5% level of signification at levels but the t-statistics are less than the critical value of t-statistic at 5% level of signification in the first difference.

Table 1. Augment Dickey-Fuller Unit Root Test results

Variables		at Level		at First Difference		Conclusion Order of integration
		t-statistic	t-statistic at 5%	t-statistic	t-statistic at 5%	
LnRM1	Constant	0.242	-2.899	-4.021	-2.900	I(1)
	Constant and trend	-2.234	-3.461	-4.013	-3.462	I(1)
IRD	Constant	-1.078	-2.902	-5.476	-2.903	I(1)
	Constant and trend	-1.778	-3.465	-5.412	-3.466	I(1)
LnRIP	Constant	-1.509	-2.908	-3.519	-2.909	I(1)
	Constant and trend	-2.862	-3.473	-3.961	-3.473	I(1)
LnER	Constant	-1.092	-2.899	-6.580	-2.900	I(1)
	Constant and trend	-2.739	-3.461	-6.542	-3.462	I(1)
LnCPI	Constant	-1.168	-2.899	-4.102	-2.900	I(1)
	Constant and trend	-2.423	-3.461	-4.245	-3.462	I(1)

Source: Researcher's calculation

¹ Hence, parameters on the logged levels measure constant elasticities and the parameters on the interest rate will show percentage changes of the dependent variable in response to a percentage point change in interest rates.

After assuring that all the variables are stationary in the first difference, I (1) we performed a VAR Lag order selection process. Table 2 reports the lag order selection criteria's statistics. The lag length of the model is selected based on modified LR test statistics (LR), Final Prediction Error criteria (FPE), Akaike's

information criteria (AIC), the Hannan and Quinn information criteria (HQIC) and the Swartz-Bayesian information criteria (SBIC). According to the three out of five criteria, specifically LR, FPE and AIC suggest to set the lag length at 4, so for our model the lag length is chosen to be 4.

Table 2: Lag Order Selection Criteria's

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	403.016				2.5e-11	-10.2055	-10.1451	-10.0545
1	816.047	826.06	25	0.000	1.2e-15	-20.1551	-19.7922	-19.2486*
2	857.232	82.369	25	0.000	8.1e-11	-20.57	-19.9048	-18.9083
3	903.93	93.397	25	0.000	4.7e-16	-21.1264	-20.1588*	-18.7093
4	940.02	72.179*	25	0.000	3.7e-16*	-21.4108*	-20.1408	-18.2383

Source: Researcher's calculation

Before we estimate the VECM, preliminary we should test for the existence of Cointegration among the real money demand (RM1), real industrial production (RIP), exchange rate of denar per euro (ER), interest rate on deposit in denar (IRD) and consumer price index (CPI) or in other words we should test the Cointegration rank using the methodology by Johansen (1988).

The results of the Johansen Cointegration rank tests are presented in Table 3. The Cointegration rank is

tested using the Trace and the Maximum Eigenvalue statistics. According to the results both Trace statistic and Maximum Eigenvalue statistics suggest that there is one Cointegration equation (vector) among the five variables at 5% level of significance. This also implies that a long run relation can be found among real money demand (RM1), real industrial production (RIP), exchange rate of denar per euro (ER), interest rate on deposit in denar (IRD) and consumer price index (CPI).

Table 3: Johansen Cointegration tests

Maximum Rank	Trace statistic	0.05 Critical Value	Max-Eigen statistic	0.05 Critical Value
None	81.7998*	68.52	41.8890*	33.46
At most 1	39.9108	47.21	21.9973	27.07
At most 2	17.9135	29.68	12.9117	20.07
At most 3	5.0018	15.41	4.9796	14.07
At most 4	0.0222	3.76	0.0222	3.76

Source: Researcher's calculation

Further on, based on the results of the lag selection criteria's statistics and the Johansen Cointegration test we chose one rank and four lags to obtain the estimation of Cointegrating relationships through a Vector Error Correction model (VECM). To estimate the long-run coefficients of real money demand and its

determinants, we must normalize one variable in the Cointegrating vector. Even from the above results we discovered that we have one Cointegration equations (vector), it is a common practice to normalize the variable of interest, which in this case is LnRM1.

Table 4: Cointegration analysis with normalization

Variables	Coefficient	Standard Error	t- statistic	p-value
LnRM1	1	-	-	-
IRD	0.1096907	0.0207785	5.28	0.000
LnRIP	-2.249412	0.5132956	-4.38	0.000
LnER	83.89734	23.26541	3.61	0.000
LnCPI	-4.122975	0.7826426	-5.27	0.000
C	-322.3076	-	-	-

Source: Researcher's calculation

Note: * indicates the rejection of the null hypothesis at 5% level. Trace statistic and Max-eigenvalue test indicates one cointegrating vectors

The long-run coefficient indicate that all the selected variables have an impact on the real money demand. Specifically, interest rate on deposit in denar and exchange rate have a negative impact on the real money demand, while real industrial production and consumer price index have a positive impact on the real money demand.

If the interest rate on deposit in denar increases by 1%, the population will be encouraged to save more and reduce the real money demand by 10.96%.² If real industrial production increases by 1%, the real money demand will get increased by 2.25%. If exchange rates increase by 1% the real money demand will decrease by 83.89%. If consumer price index increases by 1%, the real money demand will increase by 4.13%.

In Table 5 are presented the results of short-run coefficients of the Vector Error Correction (VECM)

Estimates. The short run results of our VECM model shows that the second lagged of real money demand, the second and the third lagged of real industrial production, the second and the third lagged of consumer price index had a significant impact on the current real money demand at 5% and 10% level.

If the previous real money demand increased by 1% the current real money demand will decrease by 0.23%. If the second lagged of real industrial production increases by 1% the current real money demand will decrease by 0.004%. If the third lagged of real industrial production increases by 1% the current real money demand will decrease by 0.14%. If the second lagged of consumer price index increases by 1% the current real money demand will increase by 1.09%. And if the third lagged of consumer price index increases by 1% the current real money demand will decrease by 1.42%.

Table 5: Vector Error Correction Model Estimates

Variables	Coefficient	Standard Error	z- statistic	p-value
D(LnRM1(-1))	-0.1989641	0.125658	-1.58	0.113
D(LnRM1(-2))	-0.2281812	0.123332	-1.85	0.064
D(LnRM1(-3))	0.0230211	0.1311419	0.18	0.861
D(IRD(-1))	0.0000776	0.0098039	0.01	0.994
D(IRD(-2))	-0.0042569	0.0120563	-0.35	0.724
D(IRD(-3))	0.0063833	0.0077756	0.82	0.412
D(LnRIP(-1))	-0.1558477	0.1022186	-1.52	0.127
D(LnRIP(-2))	-0.1453425	0.0834447	-1.74	0.082
D(LnRIP(-3))	-0.1414294	0.068506	-2.06	0.039
D(LnER(-1))	-6.522527	5.698192	-1.14	0.252
D(LnER(-2))	6.891624	5.797569	1.19	0.235
D(LnER(-3))	4.8255715	5.583161	0.86	0.387
D(LnCPI(-1))	-0.177888	0.6288702	-0.28	0.777
D(LnCPI(-2))	1.092087	0.6135316	1.78	0.075
D(LnCPI(-3))	-1.417346	0.621959	-2.28	0.023
ECT(-1)	-0.0623992	0.0361132	-1.73	0.084
C	0.0396639	0.0094869	4.18	0.000
R ² = 0.5691				

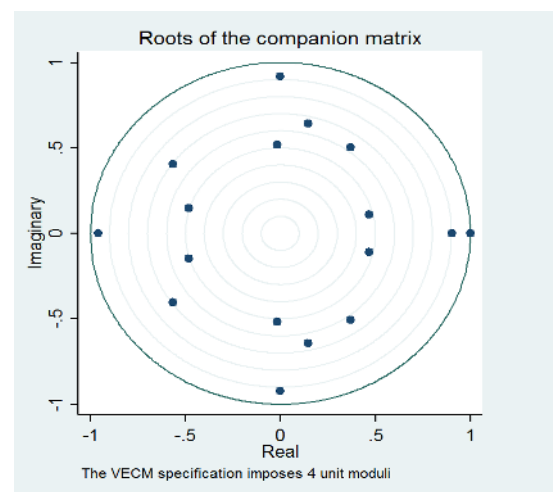
Source: Researcher's calculation

As expected, the ECT_{t-1} carries a negative sign and is significant at 10% level which confirms the long-run relationship in the Cointegration analysis. The value of the ECT_{t-1} indicates the speed of adjustment to the long-run equilibrium. From the results obtained in Table 5, the speed of adjustment in our case is about 6.24%, which means that approximately 6.24% of the disequilibrium from the previous year's shocks converge back to the long-run equilibrium and is corrected in the current year.

Our VECM has a R-Squared of 0.569, meaning that the natural logarithm of real industrial production, interest rate on deposit in denar, the natural logarithm of exchange rate of denar per euro and natural logarithm of inflation can explain up to 56.91% movement of the natural logarithm of the real money demand.

In order to fully ascertain the stability of the long-run real money demand function, the Eigenvalue stability condition is performed. The results showed that the real money demand had persisted stable since all the roots lie inside the unite circle.

Figure 1. Stability graph for VECM



Source: Author's illustration

² For this variable (IRD) we are dealing with a form of the log-linear model, so $100 \times \square (100 \times 0.1096)$ is the expected percent age change in Y for a unit increase in X.

The model is also checked for serial correlation and normality. To accomplish this, we used the LM test for autocorrelation and the Jarque-Bera test for normality. The results are presented in Table 6 and Table 7.

According to the LM test results presented in Table 6, the p-value of all the variables is greater than 0.05, so the null hypotheses in not rejected at 5% significant level of confidence, meaning that there is no serial correlation in our model.

Table 6: LM test results

lag	Chi squared	df	Prob. > Chi squared
1	32.3148	25	0.14910
2	36.1953	25	0.06869
3	16.6733	25	0.89330
4	24.7055	25	0.47897

Source: Researcher's calculation

Further on, according to the results of the Jarque-Bera test results in Table 7 the p-value of the residuals of our depended variable (LnRM1) is greater than 0.05, so the

null hypotheses in not rejected at 5% significant level of confidence, meaning that our model is normally distributed.

Table 7: Jarque-Bera test results

	Chi squared	df	Prob. > Chi squared
D(LnRM1)	0.567	2	0.75323

Source: Author's calculation

IV. SUMMARY WITH CONCLUSIONS

North Macedonia economy faced challenges in the last year's regards economic growth and maintenance of macroeconomic balances. Additionally, negative developments in the global area are reflected in added uncertainties in the North Macedonian economy. Moreover, higher food, fuel and primary commodity prices are translated into stronger foreign inflationary pressures, expansion of trade deficit and, potentially, weaker domestic demand as a result of negative effects a North Macedonian households' financial balances. Therefore, starting from this point monetary policy makers should be careful in implementing the current regime of monetary targeting. Sustainability of money demand is one of the essential factors on which it is based the choice of monetary regime.

Results provide that in the case of North Macedonia the real money demand had persisted stable throughout the analyzed period (1997-2020), we have estimated both short-and long-run money demand function, and results provide the evidence that the long-run coefficient show that all the selected variables have an impact on the real money demand. Specifically, interest rate on deposit in denar and exchange rate have a negative impact on the real money demand, while real industrial production and consumer price index increases have a positive impact on the real money demand.

The short run results of our VECM model shows that the second lagged of real money demand, the second and the third lagged of real industrial production, the second and the third lagged of consumer price index had a significant impact on the current real money demand at 5% and 10% level.

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A WORLDWIDE ISO STANDARDS TREND PERSPECTIVE ANALYSIS

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Abstract

As to ISO standards, the study is based on exploratory research to investigate the problems and the possibilities that have been presented by the International Standards organization, pulling enormous data reported by that organization. The research studies the trends in ISO standards for the period 2011-2023 by using several analytical tools, focusing on 'how' phenomena occur and concluding the key patterns found that would benefit business development. The author explains that it is necessary to invest in obtaining ISO certifications since this will pay off as a competitive advantage and provide highly relevant statistical information about ISO certificates around the world. Specifically, it addresses the question of what it means to be certified, detailing the positive effects of some of the core standards namely ISO 9001, ISO 14001, ISO 27001, ISO 37001, ISO 45001, and ISO 50001. It becomes clear that these certifications will facilitate organizations in differentiating themselves in the competitive marketplace. In this regard, the study findings stress the need to consider the adoption of the ISO standards also to have a strategic advantage.

The study also shows that ISO standards are, to some extent, interconnected and interactively multiply on organizational performance and, therefore, from a business perspective, call for a holistic approach to certification. It is with multiple standard integrations that organizations realize synergy, allowing enhanced efficiency and sustainability. The researchers are encouraged to further test the hypotheses developed since the approach of this study is indicative of paths that could be further investigated to arrive at a deepened insight into the research findings. A close evaluation may indicate how ISO standards affect near-term business performance but also have longer-term consequences for the resilience and growth of an organization within a dynamic global environment. In focusing on these dimensions, this research paper intends to bring into perspective how ISO certification informs multidimensional business strategy, operational excellence, and stakeholder trust.

Keywords: quality management, International Standards Organization, ISO standards, quality culture, ISO certification.

INTRODUCTION

The International Organization for Standardization, or ISO as it is commonly known, is a worldwide acknowledged organization that creates and disseminates international standards. These standards provide a foundation for businesses to function effectively, safely, and by rules. They encompass a wide range of industries and areas. It is critical to uphold strict standards of quality, safety, and compliance in the quickly changing corporate environment of today. Companies everywhere are working hard to satisfy these needs while maintaining sustainable and effective operations.

ISO standards are essential in assisting enterprises in accomplishing these goals. This in-depth essay will discuss the importance of ISO standards and how organizations may maintain their competitiveness and expand by becoming certified to these standards. Credibility can be increased by using certification, which shows clients that goods and services are manufactured and delivered by ISO certification standards.

For every firm, obtaining ISO certification is a noteworthy accomplishment. It distinguishes companies in a crowded market by displaying a dedication to quality, safety, and compliance.

An organization's adherence to the highest international standards is indicated by its ISO certification.

Because they can count on a dedication to quality and compliance, it fosters trust among customers, partners, and stakeholders. An organization's adherence to ISO certification fosters trust among customers, partners, and stakeholders in several key ways:

- **Demonstrated Commitment to Quality** - ISO certification indicates that an organization has implemented a rigorous quality management system. This commitment to maintaining high standards reassures customers that they will receive consistent, high-quality products or services (Fahim & Sadeghi, 2019).
- **Enhanced Credibility** - ISO standards are internationally recognized. Certification provides third-party validation of a company's processes and practices, enhancing its credibility (Zhang, 2020). This external endorsement signals that the organization meets stringent requirements.

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- Risk Mitigation - By adhering to ISO standards, organizations systematically identify and manage risks, reducing the likelihood of errors and failures (Jiang et al., 2018). Stakeholders are more likely to trust a company that actively mitigates risks, knowing that it prioritizes safety and reliability.
- Continuous Improvement - ISO standards promote a culture of continuous improvement. This ongoing commitment to enhancing processes and performance signals to stakeholders that the organization is proactive and adaptable (Sampaio et al., 2018).
- Customer-Centric Focus - ISO standards, such as ISO 9001, emphasize customer satisfaction. Organizations that prioritize understanding and meeting customer needs build stronger relationships, leading to increased trust and loyalty (Narasimhan & Jayaram, 2020).
- Consistency in Operations - ISO certification requires standardized processes and procedures, ensuring consistency in service delivery and product quality (Talib et al., 2018). This reliability fosters trust among customers who expect the same high standards every time they engage with the organization.
- Transparency and Accountability - ISO standards encourage organizations to document and review their processes, promoting transparency (McAdam & Leonard, 2003). This accountability means that stakeholders can have confidence that the organization is operating ethically and responsibly.
- Market Differentiation - In competitive markets, ISO certification can serve as a differentiator. Customers and partners often prefer to engage with certified organizations, as it reflects a commitment to excellence and responsible practices (Mokhtar & Shahin, 2018).

Through these mechanisms, ISO certification enhances operational effectiveness and builds a strong foundation of trust, fostering lasting relationships with customers, partners, and stakeholders.

Because they provide an organized approach to different parts of operations, ISO standards are essential in today's business climate. Businesses can gain from ISO certification through higher customer satisfaction, increased productivity, improved quality, and assurance of adherence to rules and regulations in the sector. The attainment of ISO certification is a fundamental aspect of both commercial and public tender selection processes, and it has the potential to enhance the success rate of corporate tenders.

A certified certification body will conduct certification audits in addition to internal audits, gap analyses, documentation, implementation, and certification audits.

Although it is not required, obtaining ISO certification has many advantages, such as enhanced risk management, expanded market reach, and elevated legitimacy.

Industries as diverse as manufacturing, healthcare, banking, and information technology can all benefit from ISO standards.

The price of ISO certification varies according on

several criteria, including the organization's size, the intricacy of its procedures, and the certifying body of choice.

MATERIALS AND PROCEDURES

Recent years have seen a significant increase in the popularity of literature on quality management, ISO standards, quality culture, quality management systems, etc., because these concepts help all types of organizations become more competitive in a thriving market where supply is significantly less than demand—one of the hallmarks of the global 21st century.

ISO STANDARDS, QUALITY MANAGEMENT, AND QUALITY

Quality is related to various concepts that influence how realistic continual improvement can be. This has to do with a few factors that affect the field's ideology, the working group, and the project participants, etc. This has been characterized by numerous writers as a social war in which supporters of an organization unite (Robbins, 1999). Subject culture pertains to individuals within the organization, their beliefs, the way they use procedures and frameworks, management, and more (Schein, 2013, 2020). This culture drives quality by involving every member of the business in quality improvement and by viewing each individual as a provider as well as a client. This is an excellent way to ensure that everything is done as well as possible right from the beginning. Regarding this, it should be mentioned that staff members shouldn't think that just because there is room for development, there isn't an issue, since this way of thinking has a significant financial cost to the company if things are not done well the first time. In order to prevent responsibility from being transferred along with processes and procedures at every level of product/service realization, it is necessary for products and services to be evaluated at every stage of implementation in companies where a quality culture is prevalent (Harvey & Green, 1993). The aforementioned speaks to four things: (1) the person who gets better with the organization; (2) tolerance and respect from other members of the organization; (3) entrepreneurial abilities; and (4) proof of ability.

Quality culture is demonstrated by the caliber of goods and services produced using standard operating procedures that are recognized, developed holistically, and found in both businesses and their cultures as well as in quality management systems (Vlăsceanu, Grünberg, and Pârlea. 2007).

Aiming for excellence, the realization of best practices and experiences to reach the standards, countries are recognized for their approach to teaching a quality culture in their universities and applying this subject there with the main principles of "training to achieve the goal" and "creating value, to create opportunities bringing benefits". The managerial approach establishes the organization's values, beliefs, and expectations, which in turn form its culture. It also defines the goals and objectives, responsible parties and their responsibilities, and the procedures and processes that are followed to achieve quality.

Lately, a great deal of work has been done in the fields of business ethics, corporate social responsibility, sustainability, and quality culture, as well as quality and its importance and relation to competitive advantage. The relationship between quality, quality culture, ISO standards, doing business, and enhancing quality of life is demonstrated by a number of studies and publications on quality, its management, total quality management, and other topics (Gordon and Owen, 2008, Harvey and Stensaker, 2008, Schein, 2013, 2020). Quality is defined by what consumers anticipate from the products and services they use and buy. This indicates that quality is conditional, highly subjective, related to perception, and concerning attributes.

According to ISO standards, particularly ISO 9001, it is said to partially satisfy customer needs, indicating that customers view quality as something they should anticipate from the good or service. Quality is what consumers want. Quality can be defined as a collection of features in a product or service that can satisfy the needs of the customer. This definition is consistent with the views expressed by Edward Deming, who wrote that "costs should be reduced, increasing productivity, and this leads to quality improvement

through management, design, testing, and processes that are constantly improving," and Peter Drucker, who said that "quality is what customers get from the product and service for which they are willing to pay." (Drucker, 1985)

It seems that meeting the requirements, desires, and expectations of consumers is at the heart of quality. Organizational management, having a strategy, concentrating on the customer, meeting the customer's needs, having qualified as a long-term commitment, working in teams, continuously improving, providing opportunities for staff education and training, granting freedom through control, and empowering and involving employees are all connected to quality management and its system. "The quality management system includes the personnel system, workplace safety, the environment, human safety, production, finance, information, development, and procurement, among other things" (Harrington and Mathers, 1997).

Quality management incorporates quality standards, the most significant of which are ISO standards released by the International Organization of Standards.

Table 1. Quality management components (table prepared by the author of this paper using literature from Juran, J. M., & Gryna, F. M. 1993, Langley, G. J., Nolan, K. M., Nolan, T. W., Norman, C. L., & Provost, L. P. 2009. Montgomery, D. C. 2013, Doligale, D. J. 2006, and Besterfield, D. H., Besterfield-Michna, C., Besterfield-Sacre, M., & Besterfield, G. 2011).

Quality management components		
No	Components	Explanations
1	Quality planning	The process of identifying and deciding how to achieve the project's quality criteria.
2	Quality improvement	The deliberate modification of a process to increase the confidence or reliability of the outcome.
3	Quality control	The ongoing effort to maintain the integrity and dependability of a process in obtaining an outcome.
4	Quality assurance	The systematic or planned actions required to provide sufficient dependability so that a specific service or product meets the defined requirements.
5	Quality goals	To guarantee that all stakeholders in the business work together to enhance the company's procedures, products, services, and culture to achieve long-term, success that stems from customer satisfaction.

Table 2. Quality management advantages (table prepared by the author of this paper using literature from Juran, J. M. 1998, Womack, J. P., & Jones, D. T. 2003, Zeithaml, V. A., Parasuraman, A., & Berry, L. L. 1990, Kotler, P., & Keller, K. L. 2016, and Deming, W. E. 1986)

Quality management advantages anagement components	
No	Advantage
1	It assists an organization in achieving more consistency in tasks and activities associated with the production of products and services.
2	It enhances process efficiency, lower waste, and makes better use of time and other resources.
3	It contributes to increased customer satisfaction.
4	It enables firms to efficiently sell their products and enter new markets, and it makes it easier for organizations to integrate new staff, allowing them to manage expansion more smoothly.
5	It allows a company to constantly enhance its goods and services, processes, and systems.

Table 3. Key benefits of using ISO standards (table prepared by the author of this paper using literature from ISO. 2014, McKinsey & Company. 2012, and ECS. 2011)

Three main types of benefits to using standards		
Key benefit	Benefits	Explanations
1	Streamlining internal operations	A key finding is that standards can be used to streamline an organization's internal process, for example by reducing the time spent on specific activities in performing various business functions, reducing waste, lower procurement costs, and increasing productivity. The case studies consistently report that the contribution of standards to the company's gross profit ranges from 0.15% - 5% of annual sales.
2	Innovation and expansion of operations	A few case studies provide examples where standards have served as the basis for innovating business processes that enable companies to expand their supplier network or effectively introduce and manage new product lies. In other cases, standards helped reduce the risk for companies to introduce new products into national markets.
3	Creating or entering new markets	Standards have been used as a basis for developing new products, and opening up new markets (both domestic and export). Supporting market acceptance of products, and even creating markets, in exceptional cases, the impact of standards went well beyond expectations, with companies generating gross profit contributions of up to 33% of their annual; sales, which helped them position themselves as leaders in their field for at least a plenty period.

Table 4: The most required ISO standards (ISO 2022)

The most required standards around the globe	
ISO 9000 family	Quality management system
ISO 10244 standard	Management of documents
ISO 14000 family	Environment protection
ISO 20000 family	Information technology
ISO 22000 family	Food quality, safety and guarantee
ISO 22301 standard	Business continuity
ISO 27000 family	Information security management
ISO 45000 family	Health and safety at work
ISO 50000 family	Energy efficiency
ISO 56000 family	Innovation management system

Table 5. Organizations' benefits of certification with ISO standards (Melo. 2020)

No	Field of ISO standard	ISO standard	Benefits
1	Enhanced Quality Management	ISO 9001	The Quality Management System standard focuses on improving product and service quality, customer satisfaction, and overall efficiency. Implementing this standard helps organizations streamline processes and deliver consistently high-quality products and services.
2	Medical Device Quality	ISO 13485	The Medical Devices – Quality Management System standard, ensures the quality and safety of medical devices, enhancing patient safety.
3	Environmental Responsibility	ISO 14001	The Environmental Management System standard, guides businesses in minimizing their environmental impact. By adhering to this standard, organizations demonstrate their commitment to sustainability and environmental responsibility.
4	Food Safety	ISO 22000	The Food Safety Management System standard, is essential for businesses in the food industry. It ensures the safety and quality of food products throughout the supply chain.
5	Information Security	ISO 27001	The Information Security Management System standard, safeguards sensitive data and ensures data security. It is crucial in today's digital age, where data breaches can have severe consequences.
6	Anti-Bribery Measures	ISO 37001	The Anti-Bribery Management System standard, helps organizations prevent bribery and corruption, fostering transparency and ethical business practices.
7	Occupational Health and Safety	ISO 45001	The Occupational Health and Safety Management System standard, prioritizes employee well-being and safety. Compliance with this standard reduces workplace accidents and promotes a culture of safety.
8	Energy Efficiency	ISO 50001	The Energy Management System standard, assists businesses in reducing energy consumption and lowering operational costs while minimizing their environmental footprint.
9	Asset Management	ISO 55001	The Asset Management System standard, helps organizations optimize asset performance and reduce costs. It is particularly valuable for asset-intensive industries.

Examples of how organizations benefit from ISO standards applications:

Here are some success stories of businesses and sectors that have benefited from implementing ISO standards:

1. **Toyota Motor Corporation:** Toyota implemented ISO 9001 to enhance its quality management systems. This standard has played a critical role in improving customer satisfaction and operational efficiency. The company's adherence to ISO standards has contributed to its reputation for high-quality vehicles and has helped it maintain a competitive edge in the automotive industry (TMC. 2019). Toyota has long been recognized for its commitment to quality management, particularly through the implementation of ISO 9001. The company's focus on continuous improvement and customer satisfaction has significantly enhanced its operational efficiency and product quality, leading to increased market share and customer loyalty (Kumar, M., & Singh, R. K. (2018).
2. **British Airways:** British Airways adopted ISO 14001 for its environmental management system, which enabled the airline to systematically reduce its environmental impact. The certification helped the company enhance its sustainability practices, resulting in reduced waste and energy consumption, while also improving its public image and compliance with regulatory requirements (BA. 2020).
3. **Nestlé:** Nestlé has implemented multiple ISO standards, including ISO 22000 for food safety management. This commitment has enabled the company to enhance its food safety processes, ensuring high standards of quality and safety throughout its supply chain. As a result, Nestlé has strengthened consumer trust and market position (Nestlé. 2021).
4. **Cisco Systems:** Cisco adopted ISO 27001 for its information security management system, allowing the company to enhance the security of its information assets. This certification has helped Cisco protect sensitive data, mitigate risks, and ensure compliance with global regulations, thereby reinforcing its reputation as a leader in technology and cybersecurity (CSI. 2019).
5. **Coca-Cola:** Coca-Cola implemented ISO 14001 to improve its environmental management practices. By adopting these standards, the company has successfully reduced its carbon footprint and enhanced sustainability practices across its operations, resulting in both cost savings and improved brand reputation (Coca-Cola Company. 2016).
6. **Boeing:** Boeing has implemented ISO/IEC 27001 to enhance its information security management system. This certification has helped the aerospace giant protect sensitive data and intellectual property, thereby strengthening its overall security posture and maintaining customer trust (Boeing. 2018).

7. **Dell Technologies:** Dell Technologies adopted ISO 50001 for energy management, enabling the company to systematically improve energy efficiency across its operations. As a result, Dell has reported significant reductions in energy consumption and operational costs, along with enhanced corporate responsibility (Dell Technologies. 2020).

These examples illustrate how diverse organizations across various sectors have harnessed the power of ISO standards to drive performance, enhance sustainability, and strengthen their competitive positions. Each case reflects a commitment to quality, efficiency, and continuous improvement, underscoring the transformative potential of ISO certification.

METHODOLOGY AND METHODS

The framework for the research was built by ISO standards certificates that were issued between 2012 and 2022. The goal of this study is to develop a theory by elucidating research problems in light of the dearth of algebraic, statistical, and numerical reasoning on the relationships between time and quality management that are represented in ISO standards.

RQ1: Has the number of ISO standards certificates issued over time increased significantly?

Methods and procedures

In particular, prior empirical research does not explain how the number of ISO standards certificates evolved

Selection of case

In this study, three primary factors were examined: (1) a theoretical framework, (2) the appropriateness of the relationships, and (3) the useful benefits that come with ISO standards certificates.

Research questions were developed in light of this. The following are the research questions:

- RQ1: Has the number of ISO standards certificates issued over time increased significantly?

A few theories were developed in response to these study questions:

H0: The number of ISO standards certificates granted over time has no changed significantly.

H1: The number of ISO standards certificates granted over time has significantly increased.

Collection of data

- Data for ISO standards – ISO website.

In preparing this research, only data taken from the International Standards Organization have been used.

Analysis of data

1. The number of ISO certificates issued from 2012 to 2022 was derived from the ISO website.
2. Using Excel, a regressive analysis of the quantity of ISO standards certificates was carried out.
3. Using Excel, a forecast study of the quantity of ISO standards certificates was carried out.

Table 6: Number of ISO standards certificates issued between 2012 – 2022 worldwide (ISO 2022)

Year	No ISO Certificates
2012	1.504.213
2013	1.564.448
2014	1.609.294
2015	1.519.952
2016	1.664.357
2017	1.556.758
2018	1.826.253
2019	1.970.029
2020	2.237.791
2021	2.689.972
2022	3.249.383

Graphic 1. Correlation between time and ISO standards certificates (graphic drawn from the author is this paper, using data from ISO 2022).

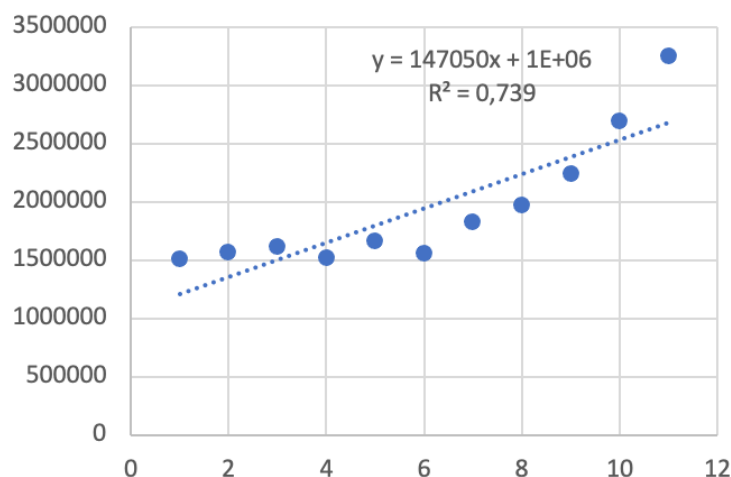


Table 7. Regression analysis summary output (table drawn from the author is this paper, using data from ISO 2022).

SUMMARY OUTPUT	
Regression Statistics	
Multiple R	0.859632
R Square	0.738967
Adjusted R Square	0.709964
Standard Error	305544.6
Observations	11

Table 8. Regression residuals and significance (table drawn from the author is this paper, using data from ISO 2022).

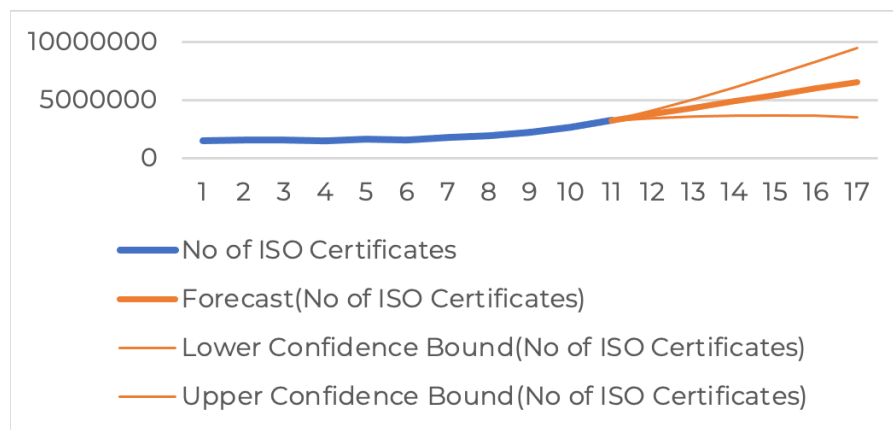
	df	SS	MS	F	Significance F
Regression	1	2.38E+12	2.38E+12	25.47843	0.000693
Residual	9	8.4E+11	9.34E+10		
Total	10	3.22E+12			

Table 9. Regression Intercept (table drawn from the author is this paper, using data from ISO 2022).

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	1062469	197586.5	5.377234	0.000446	615497.2	1509441	615497.2	1509441
Year	147049.9	29132.54	5.047616	0.000693	81147.5	212952.3	81147.5	212952.3

Table 10. ISO certificates issued forecast until 2028 (table drawn from the author is this paper)

Year	No of ISO Certificates	Forecast (No of ISO Certificates)	Lower Confidence Bound (No of ISO Certificates)	Upper Confidence Bound (No of ISO Certificates)
1	1504213			
2	1564448			
3	1609294			
4	1519952			
5	1664357			
6	1556758			
7	1826253			
8	1970029			
9	2237791			
10	2689972			
11	3249383	3249383	3249383.00	3249383.00
12		3796082.429	3457713.18	4134451.68
13		4343036.31	3617424.85	5068647.77
14		4889990.191	3697689.83	6082290.55
15		5436944.073	3709296.49	7164591.66
16		5983897.954	3659863.11	8307932.80
17		6530851.835	3554988.35	9506715.32

Graphic 2. ISO certificates issued forecast until 2028 (graphic drawn from the author is this paper, using data from ISO. 2022)

RESULTS

Summary output

The primary finding of this research is that there has been a significant increase in the number of ISO certificates globally between 2012 and 2022, and this trend seems likely to continue. This suggests that achieving ISO certification is an impressive feat that sets a company apart in a crowded market by demonstrating a commitment to quality, safety, and compliance, building trust among partners, customers, and stakeholders; additionally, because ISO standards offer an organized approach to

various aspects of operations, they are essential in today's business environment. Businesses can benefit from ISO certification through higher customer satisfaction, increased productivity, improved quality, and assurance of adherence to rules and regulations in the sector. Obtaining ISO certification is a crucial component of the selection processes for both commercial and public tenders, and it can increase the success rate of corporate tenders.

While not mandatory, ISO certification offers several benefits, including improved risk management, increased market reach, and increased legitimacy.

Research's context

When combined with other strategies like creativity, innovation, intellectual property, etc., quality management—embodied at ISO standards—can provide a competitive edge in a changing market. Previous empirical research has shown that, in addition to several significant theoretical studies demonstrating the significance of quality management and ISO standards certification, there are few studies on the subject that are mathematical, statistical, and algebraic as well as theoretically approached.

DISCUSSION

Based on the study's final findings, a new avenue for further research has been opened in the still-unknown domain of the ISO certificate number increase and its relationships with other domains and patterns like economic growth, intellectual property, quality of life, etc. The main finding of a regressive analysis is the significance of the ISO certificates number increase and about the observations for theory and practice. In terms of application, the study emphasizes how important it is to see the relationships between ISO standards certificates, notable business accomplishments and economic growth, intellectual property, and quality management as a triangle because doing so aids in the development of stronger competitive advantage strategies by businesses and the country's economy as a whole. Besides that, it is essential to consider other influencing factors, such as economic growth, intellectual property rights, and quality of life, which may also impact the number of ISO certifications granted over time.

- **Economic Growth** - Economic growth often correlates with an increase in ISO certifications. As economies expand, businesses seek to enhance their competitive edge and operational efficiencies, often turning to ISO standards as a means of achieving these objectives. A study by Gibbons and Wood (2019) highlighted that countries with robust economic growth tend to adopt ISO standards more rapidly, as businesses strive to meet both domestic and international market demands (Gibbons, J., & Wood, D. 2019).
- **Intellectual Property Rights** - The protection of intellectual property (IP) can also influence the number of ISO certifications. Strong IP rights can encourage innovation and quality management practices within organizations, prompting them to seek ISO certification to safeguard their processes and products. A study by Maskus (2017) found that nations with stronger IP protection frameworks are more likely to see an increase in ISO certification as companies aim to align with international quality standards and protect their proprietary technologies.
- **Quality of Life** - Quality of life indices can also correlate with the adoption of ISO certifications. Higher

quality of life often leads to increased consumer expectations regarding product quality and safety. Organizations, in turn, may pursue ISO certification to meet these expectations and enhance their market position. Research by Sweeney and Soutar (2020) indicates that regions with higher quality of life ratings tend to have more businesses pursuing ISO certifications, driven by a consumer base that prioritizes quality and ethical practices.

Incorporating these additional factors—economic growth, intellectual property rights, and quality of life—into the analysis provides a more comprehensive understanding of the dynamics influencing the number of ISO certifications over time. By exploring these interrelated aspects, researchers can gain deeper insights into the broader context of ISO certification trends and their implications for organizations globally.

LIMITATIONS AND AVENUES FOR FURTHER RESEARCH

This article attempts to answer these concerns by highlighting recurring problems with understanding the relationships between ISO standards, notable corporate achievements, and trends like economic growth, intellectual property, and quality of life. The research presented in this paper provides a window for other scholars and practitioners working in similar disciplines, since we are now much closer to being able to design studies that will be able to provide better answers to such concerns. Further research is being done on the systems that enable these relationships, however at this point there is enough data to offer some conclusive responses to queries about these relationships.

Using comprehensive data on these topics from 2012 to 2022, this study is the first of its type to examine the relevance of ISO certificate number increases; nevertheless, additional research is required to ascertain whether these correlations persist.

I can argue that future research should: Think about likely interactions between variables that might be particularly relevant to the topics being studied; however, keep in mind that researchers don't need to consider every possible interaction; instead, they should concentrate their data collection efforts on testing explicitly defined interactions. Additionally, information that would demonstrate connections between ISO standards certificates and economic growth, intellectual property, and QM at the level of countries and economies should be gathered.

CONCLUSIONS AND RECOMMENDATIONS

1. According to the study's final findings, a new line of inquiry into the as-yet-unknown subject of the ISO certificates number increase and its relationships with other domains and patterns like economic growth, intellectual property, quality of life, etc., has been opened. The main finding of a regressive analysis is the significance of ISO certificates number increase and about the observations for theory and practice. In terms of application, the study emphasizes how important it is to see the relationships between ISO standards certificates, notable business accomplishments and economic growth, intellectual property, and quality management as a triangle because doing so aids in the development of stronger competitive advantage strategies by businesses and the country's economy as a whole.
2. What matters most, though, is that this study's regression analysis of the importance of ISO standards certifications growth yielded statistical results for the first time.
3. The rise in ISO standards certificates, which has been statistically shown to be significant, ought to be linked to other trends such as economic expansion, quality control, intellectual property, and living quality, among others.

Conflict of interests

The author declares no conflict of interest.

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REVOLUTIONIZING COURSE SELECTION IN HIGHER EDUCATION: A HIDDEN MARKOV CHAIN-BASED RECOMMENDER SYSTEM

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Abstract

Course recommendation systems have a significant role in providing personalized educational suggestions through the analysis of student preferences, course information, and their interactions. This paper presents a sequential course enrollment recommendation system using the Hidden Markov Chain method. The system analyzes students' academic records, including past course selections and grades, to create student-specific recommendations. The recommendation process is framed as a sequential optimization problem in which the system calculates a new list of course preferences based on the student's academic background. The study includes the use of the success rates of the hidden and observed matrices derived from the Hidden Markov Chain to perform prediction tasks. These matrices are created with data based on all targeted transitions from technical courses to elective courses and success rates. Viterbi and entropy concepts are additionally utilized to constitute the Hidden Markov Chain method while considering the students' selection and the outcome, the compatibility of the course contents with each other, and the course preference and success of other students. Experimental results based on multiple experiments and various parameters outperform the traditional Markov Chain implementation by 0.15 on average accuracy. The proposed system has the potential to improve the course selection experience for students, allowing for improved academic outcomes.

Keywords: Course Recommendation, Sequential Recommendation, Markov Chains, Collaborative Filtering, Higher Education, Hidden Markov Chain, Observed Matrix, Hidden Matrix

INTRODUCTION

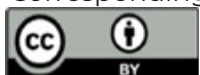
The rapid progress of the Internet has given rise to the challenge of information overload and creating difficulties in locating desired information. So far, personalized recommendation systems have emerged as the most effective and encouraging approach to tackle the problem of information overload (Zhou & Wenbo, 2019). Recommendation systems are prevalent in effectively all digital platforms and have a significant role on the decisions we make, the products we purchase, and the movies we watch (Warnes and Smirnov, 2020; Shani et al., 2005). Recently, recommender systems have been applied in a wider range of fields, including the education sector, particularly in higher education. Systems that recommend courses are particularly relevant among recommender systems for academic decisions (Campos et al., 2014).

In today's educational landscape, learners face numerous challenges when making the right career choices. One of the primary challenges college students encounter is creating and handling their

course schedule for the semester (Bydžovská, 2016). With the availability of online university admissions, students are faced with selecting from a vast array of courses, often without sufficient guidance or support (Chen et al., 2017). In this process, recommender systems can be used to assist students on an individual basis. In this study, a course recommendation system was designed for a student automation application that includes student and course information in the ESOGU course management system.

When dealing with large collections of items, recommender systems (RS) are aimed at helping users in information access and retrieval applications (Campos et al., 2014). There are several techniques to create a well-performing course recommender system (CRS): content-based systems, collaborative-filtering systems, and popularity-based ranking systems (Shen et al., 2013). Collaborative filtering (CF) has recently become increasingly popular and effective. CF can be categorized into memory-based or model-based approaches. Memory-based techniques utilize user-item databases to predict users' item preferences by

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leveraging the preferences of similar users who share common interests within a group (Mlika and Karoui, 2020). This traditional recommendation system provides recommendations based on users' past preferences and similar users' choices. However, this approach is often limited to a fixed and narrow time frame.

In this study, a new recommendation system is designed using the Markov chain method to model users' past preferences and provide a more flexible time framework for future recommendations. The Markov chain models a state sequence that represents the user's past preferences. This model then predicts the user's future preferences based on their past choices.

The main contributions of the paper are summarized below.

- A Markov chain system-based recommendation approach is proposed, along with the consideration of the grades received by students from the courses.
- Labels and weights are applied to the courses and course contents. Thus, a probability-based recommendation system was developed. The weighting of courses and tags provided by a university based on their importance levels enabled us to achieve relative impact in predictions.
- Instead of directly calculating probabilities, the Viterbi concept was employed to evaluate the proximity of each path to the maximum path value within its target group.

The rest of the paper is organized as follows. The next section provides a reference to previous research and draws attention to the methods we utilize. Section 3 presents the material and methods that are realized in our research. Section 4 presents the experimental design for course recommendation, including the recommendation engine and testing criteria. The study is concluded in Section 5, which also discusses potential future research plans.

RELATED WORK

One of the goals that universities aim to accomplish is to provide guidance to students on which courses to enroll in (Bhumichitr et al., 2017). This section examines various methods to help students choose a limited number of courses for enrollment in the upcoming semester.

Recent research in course recommender systems has explored varied approaches. Collaborative filtering leverages user-item interaction data to identify similar users or items and make personalized recommendations, while content-based filtering analyzes the content of courses and recommends similar courses based on relevant features (Nurakhmadyavi and Wahyudi, 2024). The hybrid methodology can combine different techniques (Gulzar et al., 2017).

In a study, a Markov chain model is employed to enhance the performance of recommendation systems by predicting future preferences based on a user's past choices and behaviors. The researchers conducted experimental studies to demonstrate the effectiveness of MCRS in accurately predicting user

preferences. This study offers a novel approach to the development of recommendation systems and suggests that Markov chain-based recommendation systems can enhance the user experience (Zhou and Wenbo, 2019). A student program recommendation system was developed by Booker (2009), which takes the keywords of the users' interests and their current GPA scores as input. The system employs a content-based filtering model and unlike the study we conducted does not evaluate information regarding students' grades. Additionally, the presented prototype in the study is designed to provide recommendations about suitable programs for students and support the program selection process (Booker, 2009).

In the literature, there are course recommendation systems carried out with different techniques using the Markov Chain method. Polyzou and colleagues assume that students' choices for the next semester depend on the courses they have taken so far. It establishes a Markov chain through courses for each degree program (Agoritsa et al., 2019). Elham S. Khorasani and colleagues have suggested a Markov Chain Collaborative Filtering approach to make course recommendations based on past academic records, considering the order in which each course was taken (Khorasani et al., 2016). CF methods are based on the principle that individuals who have similar preferences for items in the past are likely to have similar preferences for items in the future (Bakhshinategh et al., 2017). Hana presents a mechanism that utilizes this approach to suggest suitable courses for a student by examining their academic record and comparing it with the records of others to determine similarity (Bydžovská, 2016). A proposed system by Amer Al-Badarenah and Jamal Alsakran recommends elective courses for students by considering both their grades and similarities with other students (Al-Badarenah and Alsakran, 2016). Another study presents research on the design of a personalized recommendation system for learning resources based on collaborative filtering. Conducted by researchers Mingxia Zhong and Rongtao Ding, this study utilizes collaborative filtering method to recommend suitable learning resources to students. The aim of the study is to enhance students' learning experiences and facilitate their access to resources that meet their needs. Collaborative filtering method considers users' personal preferences and interests to provide customized recommendations (Zhong and Ding, 2022). In a different study using the Hidden Markov Model, HMMs are utilized to determine students' academic performance levels. The developed HMMs are employed to classify students' academic performance in a standardized and intuitive manner. This classification aims to represent students' academic performance levels in a more comprehensible way. The use of HMMs provides a tool for understanding students' academic performance trajectories and investigating the relationship between different performance levels and final academic outcomes (Boumi, 2022).

The recommender system discussed in the paper is centered on identifying past course data among students by analyzing their academic records. The grades that the students took from the courses were also added to the Hidden Markov Chain. In addition, the study incorporated the grading system as an essential component for analyzing academic records within the recommender system. This was done to facilitate the identification of similarities among students based on their academic performance.

MATERIALS AND METHODS

This section typically encompasses the origin of the dataset and the modifications made to the data through code-based edits, additions, and deletions prior to its processing. These adjustments have enhanced the data comprehensibility and usability.

Dataset:

The dataset consists of the letter grades and scores of Eskisehir Osmangazi University computer engineering students between 2010-2020. The post-2020 records were not taken into consideration due to the courses mostly being switched to online education and the inconsistency of data during this unusual period. Considering that students choose non-compulsory courses according to their own wishes, operations were carried out using the data of elective courses in the dataset.

Preprocessing:

The dataset contains compulsory and non-compulsory courses. Non-compulsory courses are chosen by students based on their future specializations (Ceyhan et al., 2022). The motivation is that students with the same specialization tend to take similar courses and achieve success in line with their choices. The dataset is structured by classifying the courses according to their contents and qualifications to facilitate its use in the system later. The classified categories include information such as course credits, elective status, and whether the course was offered in the current year. This classification helps separate courses that may lead to misinformation during the process. Since the online education system and pandemics were new after 2018, the data contains deviations and inconsistencies. In the evaluation of the trained data in the conducted research, the last regular data from the first quarter of 2018 and before the pandemic was used as the test dataset. Course information in the dataset is listed with course IDs, years of offering, and periods. This allows us to determine which courses the retrospective students took, when they took them, what grade they achieved, and identify relationships based on these key IDs. The student data includes student ID, GPA, and the list of courses taken during semesters. The numerical values corresponding to the letter grades are shown in Figure 1. Grades for courses that students do not take are assigned a value of 0. Courses with 'DZ' letter grades indicate that students do not pass due to absence, and non-credit courses are excluded from the training set (Arık, Okyay, and Adar, 2021). This way, previously

taken courses are excluded from suggestions based on the student ID, creating a reliable suggestion environment.

Letter Grade	Numerical
AA	4.0
BA	3.5
BB	3.0
CB	2.5
CC	2.0
FF	0.0

Figure 1. Letter Grades

Chain Implementation:

Markov Model was taken as a basis to obtain the method needed in the estimation process. It is aimed to reveal different probabilistic connections by adding another matrix to the classical Markov chain model with a single matrix. The Hidden Markov Chain method and two transition matrices used to predict course recommendations are shown in Figure 2. The first of these transition matrices is called "Observed Matrix," representing courses in the department, indicating their correlation values between. The second one is called "Hidden Matrix" and represents a more abstract correlation between pre-defined course tags. The Markov model and two transition matrixes are shown in Figure 2.

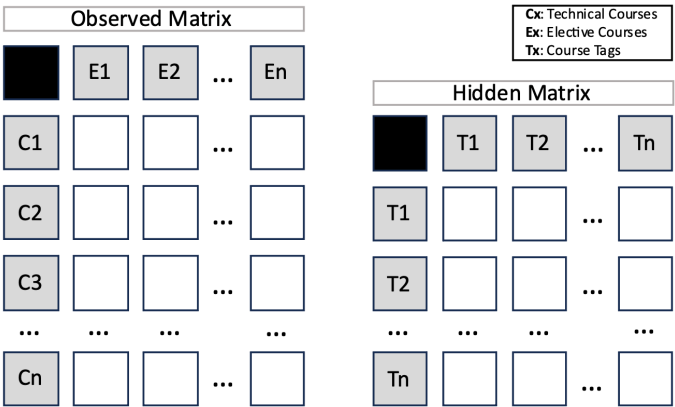


Figure 2. Matrix Representation

For the Observed Matrix, values are determined by the probability of successful course transitions. For Hidden Matrix, values determined by the probability of successful transitions between course tags are weighted by course credit.

Elective courses from technical courses in the range of previous semesters are recorded and combined to fill the matrix as success rates. This part of the implementation stands as the foundation of the Markov Model. Onto the basic model, other improvements are implemented and tested to create an optimized predictor.

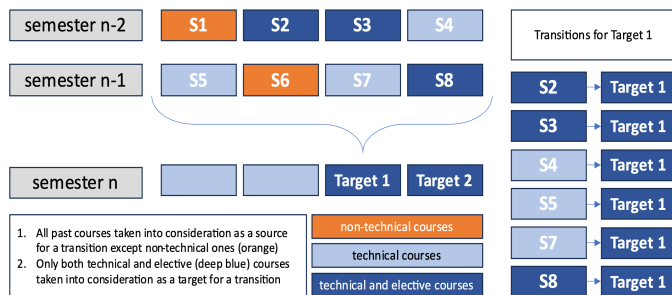


Figure 3. Transition Extraction

Hidden Matrix includes course tags defined in the course script as both rows and columns therefore it is a square matrix. The process of filling the Hidden Matrix is the same as filling the Observed Matrix. The only difference is that in describing a transitions value in terms of numbers, credits of the courses are distributed on lesson labels weights of the courses. The course labels mentioned here are defined by ESOGU. The course labels are used by distributing the course credit amounts to these labels' weights.

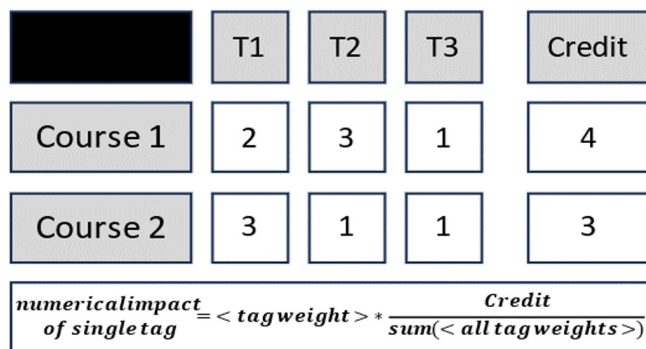


Figure 4. Weighting for Hidden Matrix

This process is implemented to set a tag weight to every tag in the course to differentiate the significance of the lesson label for the specific course and to set a single course weight among all courses to differentiate course significance. As shown in Figure 4, a matrix has been created to assign a label weight to each label in the course. For each course, the label and credit value have been placed in the matrix, and the specified operation has been applied. As a result, the importance of the label for a particular lesson is determined, and the calculated transition values are used in the Hidden matrix.

Once the matrices are created with training data, a prediction algorithm is needed to run on the matrices to recommend courses. In this study, two methods are combined and implemented onto the classical Markov Chain prediction system. What is called a classical Markov Chain prediction system simply depends on finding path probabilities of states and returning it as the probability of the transition to happen.

In this study, besides the classical estimation technique, the concepts of Viterbi and entropy difference were adapted in the estimation process and added to the study as an additional method. In a single prediction process, for each matrix; algorithm calculates the Viterbi (maximum probability value in the set to transit to target) value of the target state and returns the entropy difference between the Viterbi and transition probability value. It calculates how close the transition probability value is to the Viterbi value, and the calculated value is set as the prediction point of the target course. The aim of this process is to alter the probability of transaction happening to more inter-pretable representation by calculating relative transaction values.

This process is executed for every course possible for students to take in the current semester, and a list is created by combining the final value of each transition calculation. To create a whole recommendation list for a student, algorithm iterates through the student's past course preferences and creates recommendation lists for each course. After the calculation of single courses, results are combined to create a final prediction array. Overall mapping of the system can be seen in Figure 5.

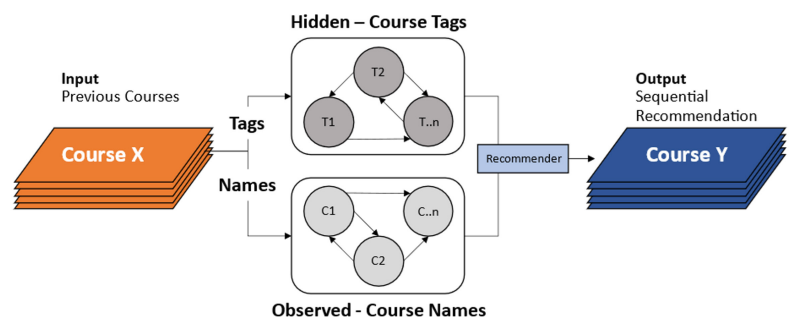


Figure 5. Overall Process

EXPERIMENTAL DESIGN

This section presents the experimental design of our sequential course enrollment recommender system, focusing on different parameters for the succession and cutting of the prediction array. The algorithm was evaluated using various criteria for success, including values of 3.0, 3.5, and different cutoff points, such as the top 3, 4, and 5 predictions. In addition, ESOGU's definition of "Student with a weighted grade point average of at least 2.00 is considered successful" is also included.

The concepts of success criteria implemented in this study are derived from various sources. The 3.0 success point is used (Ceyhan et al., 2021) as the valid succession grade. On the other hand, the method applied by the school to determine if a student failed or passed the course is implemented - This criterion is referenced in Figure 6 and Figure 7 as "Pass." Lastly, the 3.5 success point was added for experimental purposes. At this point, the dimension of the prediction array is an important consideration, determined by the current semester's available courses. Seven elective courses were available during the test phase, which influenced the number of recommendations generated. The change in the number of courses suggested is within the range of 3-5, which is a middle range, far from both ends of the number of courses. This approach aims to maintain data consistency without reaching the limits of the course list.

Furthermore, a classical statistic-based Markov Chain was implemented to compare the results of the optimizations made in this study with the performance of the classical implementation. This action aims to measure the contributions of concepts like course labels, Viterbi, and entropy difference implemented with the Hidden Markov model. By comparing the outcomes of the sequential course enrollment recommender system constructed in this study with the results obtained from the traditional Markov Chain approach, a comprehensive comparison can be made to evaluate the effectiveness of the proposed methods of optimizations in this study. The experimental design involved comparing different combinations of success criteria and the number of recommendations to identify the optimal settings for the system. The effects of the parameters were analyzed by evaluating the metrics of the generated recommendations.

In conclusion, the experimental design was designed to assess the performance of the sequential course enrollment recommender system under various conditions and settings. It provides valuable insights into the effectiveness and performance of the recommender system, offering a comprehensive understanding of its capabilities.

RESULTS AND DISCUSSION

Firstly, comparing the thresholds, it was observed that using a passing point of 3.5 resulted in higher accuracy and sensitivity/recall compared to the passing point of 3.0 and the passing criteria determined by the school. This indicates that setting a higher passing point can improve the system's ability to identify positive instances correctly. However, precision values tended to be higher when the passing point was set to 3.0, suggesting a higher proportion of relevant recommendations.

Optimized Markov Model Result Metrics

		Accuracy	F1 Score	Precision	Recall	Specificity
Cut 3	3.0	0.6752	0.6041	0.6041	0.6041	0.8064
	3.5	0.7264	0.6190	0.6046	0.6341	0.7763
	Pass	0.4358	0.5352	0.6666	0.4470	0.4062
Cut 4	3.0	0.6923	0.7000	0.6461	0.7636	0.6290
	3.5	0.6324	0.5742	0.4833	0.7073	0.5921
	Pass	0.4615	0.5882	0.6617	0.5294	0.2812
Cut 5	3.0	0.6581	0.7014	0.5949	0.8545	0.4838
	3.5	0.5897	0.5789	0.4520	0.8048	0.4736
	Pass	0.5897	0.7176	0.7176	0.7176	0.25

Figure 6. Optimized Markov Model Result Metrics

Secondly, considering the cutoff points, increasing the cutoff point from 3 to 4 led to improved performance in terms of accuracy, precision, sensitivity, and F1 score. This indicates that considering a larger number of top recommendations can enhance the system's ability to make accurate pre-dictions. However, when the cutoff point was set to 5, there was a decrease in performance across most metrics, suggesting that including too many recommendations might introduce noise and lower the system's precision.

Classical Markov Model Result Metrics

		Accuracy	F1 Score	Precision	Recall	Specificity
Cut 3	3.0	0.5384	0.4000	0.3673	0.4390	0.5921
	3.5	0.5555	0.4090	0.3829	0.4390	0.6184
	Pass	0.4529	0.5223	0.7142	0.4117	0.5625
Cut 4	3.0	0.5042	0.4081	0.3508	0.4878	0.5131
	3.5	0.4957	0.3917	0.3392	0.4634	0.5131
	Pass	0.4615	0.5771	0.6718	0.5058	0.3437
Cut 5	3.0	0.4871	0.4642	0.3661	0.6341	0.4078
	3.5	0.4273	0.4273	0.3289	0.6097	0.3289
	Pass	0.5726	0.7058	0.7058	0.7058	0.2187

Figure 7. Classical Markov Model Result Metrics

Comparing the impacts of different parameter combinations, the configuration with a passing point of 3.0 and a cutoff point of 4 emerged as the most favorable. This combination demonstrated high accuracy, precision, sensitivity/recall, specificity, and F1 score, indicating a well-balanced performance in predicting course enrollments. However, it is important to note that the optimal parameter settings may depend on the specific goals and requirements of the course enrollment system.

The comparison between the classical model of Markov Chain and the proposed algorithmic design in this study reveals that, on average, the accuracy of the recommender system improved by 0.15. This improvement indicates that the proposed algorithmic modifications and techniques implemented in the proposed design have contributed to a more accurate recommendation process.

Additionally, the comparison underscores that the system's stability becomes more fragile when exposed to varying conditions in the classical Markov Model implementation. The proposed design, with its refined algorithms and techniques, has created a more balanced recommendation process with higher-valued metrics. By fine-tuning the parameters and optimizing the algorithm, the system achieves improved accuracy and a more robust performance.

In summary, adjusting the passing point and cutoff point parameters can significantly influence the performance of the sequential course enrollment recommender system. Higher passing points can improve positive instance identification, while lower passing points tend to result in higher precision. Increasing the cutoff point enhances overall performance, but selecting an excessively large cutoff point may introduce noise. Choosing the most suitable parameter settings requires careful consideration of the desired trade-offs and objectives of the recommender system.

The comparison between the classical model of Markov Chain and the optimized algorithmic design demonstrates that the optimized design outperforms the classical implementation, resulting in higher accuracy and improved system balance.

CONCLUSIONS

In this paper, we proposed a sequential course enrollment recommender system based on the Hidden Markov Chain method to address the challenge of course selection faced by college students. The system utilizes students' academic records, including past course choices and grades, to generate personalized recommendations. By framing the recommendation process as a sequential optimization problem, the system computes a new list of course preferences based on the student's academic history. Experimental results demonstrated the effectiveness of the proposed system, surpassing traditional Markov chain implementations. Incorporating Hidden and Observed Matrices derived from the Hidden Markov Chain allowed for accurate prediction tasks. The system considered the grades received by students from courses, applying labels and weights to courses

and course contents, which resulted in a more precise recommendation system.

The study contributes to the field of course recommendation systems by introducing the use of the Hidden Markov Chain method and incorporating grading systems as an essential component for analyzing academic records. By considering the order in which courses were taken, the system provided more flexible time frames for future recommendations. The personalized recommendations offered by the system have the potential to enhance the course selection experience for students, leading to improved academic outcomes.

Future research can explore further enhancements to the system, such as incorporating additional factors like students' interests, career goals, and feedback on previous course recommendations. Moreover, the system can be extended to handle larger datasets and consider real-time updates in academic records. Evaluating the system's performance across different educational institutions and diverse student populations would also be valuable for its broader applicability. Overall, the presented sequential course enrollment recommender system offers a promising approach to assist college students in making informed course selection decisions. By leveraging the Hidden Markov Chain method and analyzing academic records, the system provides tailored recommendations that align with students' past choices and grades. The system has the potential to contribute to improved academic experiences and outcomes for students in higher education. In addition to the proposed enhancements mentioned in the conclusion, future research in course enrollment recommendation systems should focus on incorporating relative grade values for students based on their personal success and the overall distribution of grades within specific courses. This approach would provide more personalized and accurate recommendations by considering a student's relative performance compared to their peers, as well as accounting for the difficulty of the course and the individual's capabilities. Moreover, analyzing the distribution of grades across all students in a course would refine the recommendation process, helping guide students toward courses that align with their abilities and provide a balanced workload. Additionally, integrating qualitative feedback from students regarding their course experiences and the relevance of recommended courses would allow for continuous improvement and fine-tuning of the recommendation algorithm. These advancements would contribute to a more comprehensive and accurate course recommendation system, ultimately enhancing the academic journey for college students.

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A SMART DATA-DRIVEN DIAGNOSIS FRAMEWORK FOR LOWER BACK PAIN ANOMALY DETECTION

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Abstract

Spinal disorders are becoming increasingly common in the teenage years, and many adolescents, including children, suffer from pain and distress caused by such problems. Several variables, including poor sitting posture, prolonged posture fatigue, and regular use of electronic devices, have caused an increase in the occurrence of spine problems in teenagers. Therefore, to prevent it from getting worse in older ages, it is essential to determine whether lower back pain is abnormal at an early stage. Recent advances in artificial intelligence technologies in the field of spine surgery are promising in assisting specialists in early diagnosis. In this study, a publicly accessible dataset is analyzed to diagnose spinal disease using machine learning algorithms. After removing outlier values and scaling data, correlation analysis is performed to evaluate the effect of independent variables on the dependent variable. During the experiments, various classification algorithms, including Random Forest, Gradient Boosting, Extreme Gradient Boosting, Extra Trees, and Bagging, were compared to determine the best model in terms of accuracy and efficiency. Among these, the Bagging classifier achieved the highest precision (84.8%), recall (88.6%) and F-score (86.7%), indicating superior performance in diagnosing spinal anomalies. These findings demonstrate the potential of machine learning algorithms to enhance diagnostic accuracy and support early detection in smart healthcare systems to diagnose lower back pain.

Keywords: Lower back pain, machine learning, classification, AI in healthcare.

INTRODUCTION

Spine problems are today's most common disease due to poor sitting habits, posture fatigue, and increased use of electronic devices, which has led to increased spine disorders prevalence in adolescents. In order to prevent lower back pain from becoming worse in older persons, early diagnosis is crucial.

The early diagnosis of lower back pain, can prevent the condition from worsening at older ages, especially in adolescents. Studies have shown that lower back pain is prevalent in adolescents, particularly in the context of sports activities (Trompeter et al., 2017). Furthermore, the chronic nature of lower back pain emphasizes the need of early detection in order to avoid its advancement into a more severe state (Bennett, 2022). Tetsuka et al. (2020) have highlighted the need for early diagnosis and treatment of spinal illnesses such as spinal epidural abscess. They have also highlighted the need for timely intervention to prevent complications. This is especially important for young athletes, since differential diagnosis plays a critical role in identifying specific causes of low back pain (Patel & Kinsella, 2017). The prevalence of lower back pain in sports, the chronic nature of the condition, the importance of differential diagnosis in young athletes, and the development of screening algorithms emphasize the importance of early diagnosis and intervention in spinal disorders among adolescents.

These results suggest that modern diagnostics could be integrated with state-of-the-art technology for treating low back pain in its early stages and for beginning the prevention of it getting worse among older adults.

Artificial intelligence (AI) technology, which has shown significant advancements recently, has been provided great opportunities for the early identification of diseases related to the spine. The literature review has showed that AI is used very widely in the diagnosis of various spinal diseases, as well as predicting their outcome (Azi-mi et al., 2020). The study has also emphasized the way AI and its algorithms have improved the assessment of the diseases of the spine, pointing out to the great potential for its early diagnosing and treatment. The potential benefits of AI have been proved for the imaging of spinal metastases technique that can help doctors in the minimization of side effects and improvement of the efficiency (Ong et al., 2022). Nam et al. (2020) also found that there is a significant interest in the integration of AI with digital biomarkers and the Internet of Things within the context of spine care. It shows the potential of AI for current and future applications in the prevention and early detection of spinal disorders. According to Zhang et al. (2024), the accelerated advances in the application of the current AI technology could reportedly help experts diagnose

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spine diseases in the early stages, improving patient outcomes and healthcare delivery quality. In recent research, the use of machine learning (ML) algorithms to diagnosis the lower back pain in adolescents has attracted remarkable interest. Researchers have tested and proved the use of AI techniques in diagnosing the imaging of spinal metastasis, representing a potential opportunity for diagnosing spinal diseases including the lower aspect in the adolescence period (Ong et al., 2022). The development of AI-based techniques to detect spinal muscular atrophy, the use of AI to identify spinal muscular atrophy, and the application of AI in spine diseases are gaining importance (Taleb, 2024; Santana et al., 2020; Sharma et al., 2022). Furthermore, according to the results of the study on the development of multidisciplinary guidelines based on evidence and consensus for the diagnosis of back pain in children and adolescents, priority should be given to using cutting-edge technology, such as ML, for accurate and effective diagnosis (Frosch et al., 2022). Moreover, Pandey et al. (2022) suggests that it is promising to use ML algorithms to classify and automatically diagnose lower back pain based on gait patterns in diagnosing lower back pain in teenagers. In a study, a stacked ensemble approach is proposed for detecting lower back pain (Bandyopadhyay & Dutta, 2020). The aim of this study is to utilize recent advances in AI to determine the diagnosis of spinal disease in an early stage. The proposed method includes various steps. The first stage in data preprocessing involves removing outliers and normalizing the data. Next, a correlation analysis is performed to determine the importance of independent factors on the dependent variable. Next, a comprehensive analysis of several ML algorithms is conducted to interpret the outcomes of the algorithms by using a publicly available dataset is used. The remainder of this paper is organized as follows: Section 2 provides an overview of the materials and methods used in this study, including the dataset definition and exploratory data analysis, and model construction, highlighting the performance evaluation of various classification algorithms. Section 3 presents the experimental setup and test results. Finally, Section 4 concludes the study and outlines future studies.

MATERIALS AND METHODS

In recent research, the use of ML algorithms in diagnosing lower back pain in adolescents has attracted great attention. By considering the physical angle of the human bone, this study proposes an effective method for predicting spinal diseases. We analyze and diagnose spinal diseases using a publicly accessible dataset. In the preprocessing step, the outlier values are removed from the dataset and the data is normalized to improve the efficiency of the ML algorithms. Then, we use correlation analysis to assess the influence of independent variables on the dependent variable, which is the presence of lower back pain. Then, we test various classification algorithms to develop an efficient model for diagnosing lower back pain in adolescents.

Dataset Definition and Exploratory Data Analysis
We analyze and diagnose spinal diseases using a publicly accessible dataset. We down-loaded the dataset from the Kaggle website. We used the dataset as a dichotomous classification problem to determine the health of the spine by collecting physical data from the human spine, pelvis, and other parts. The dataset contains 310 total observations with 13 attributes, of which 12 are numerical features (independent variables) and one remaining attribute is a categorical feature (dependent variable). The characteristics of the dataset are given in Table 1.

Table 1 The variables in the dataset

Name	Variable Type	Domain Type	Abbreviation
Pelvic incident	Independent	Continuous	x_1
Pelvic tilt	Independent	Continuous	x_2
Lumbar lordosis angle	Independent	Continuous	x_3
Sacral slope	Independent	Continuous	x_4
Pelvic radius	Independent	Continuous	x_5
Degree spondylolisthesis	Independent	Continuous	x_6
Pelvic slope	Independent	Continuous	x_7
Direct tilt	Independent	Continuous	x_8
Thoracic slope	Independent	Continuous	x_9
Cervical tilt	Independent	Continuous	x_{10}
Sacrum angle	Independent	Continuous	x_{11}
Scoliosis slope	Independent	Continuous	x_{12}
Normality	Dependent	Categorical	y

The statistical analysis of the independent variables is given in Table 2.

Table 2 The statistical analysis of the independent variables

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
count	310	310	310	310	310	310	310	310	310	310	310	310
mean	60,49	17,54	51,93	42,95	117,92	26,29	0,47	21,32	13,06	11,93	-14,05	25,64
std	17,23	10,00	18,55	13,42	13,31	37,55	0,28	8,63	3,39	2,89	12,22	10,45
min	26,14	-6,55	14	13,36	70,08	-11,05	0,003	7,027	7,03	7,03	-35,28	7,01
25%	46,43	10,66	37	33,34	110,70	1,60	0,22	13,05	10,41	9,541	-24,28	17,18
50%	58,69	16,35	49,56	42,40	118,26	11,76	0,47	21,90	12,93	11,95	-14,62	24,93
75%	72,87	22,12	63	52,69	125,46	41,28	0,70	28,95	15,88	14,37	-3,49	33,97

Figure 1 displays the distribution of instances for the class variable. As seen in Figure 1, there are 210 instances in Class 1 ("Abnormal") and 100 instances in Class 0 ("Normal").

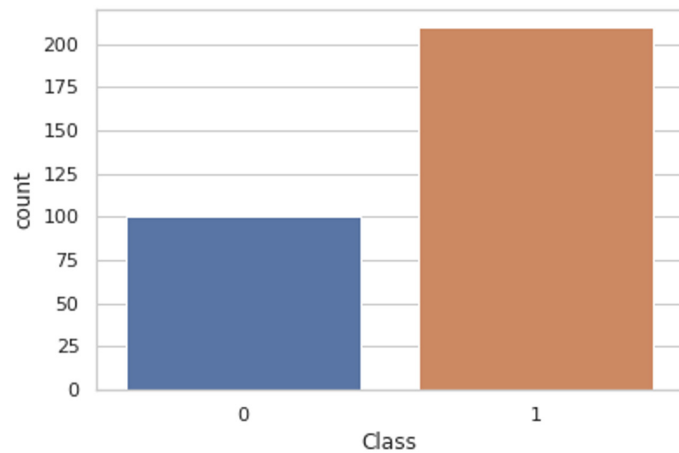


Figure 1. The distribution of the dependent variable

The statistical representation to show the distribution of the dataset is given in Figure 2. The heat map for correlation coefficient values in the dataset is given in Figure 3.

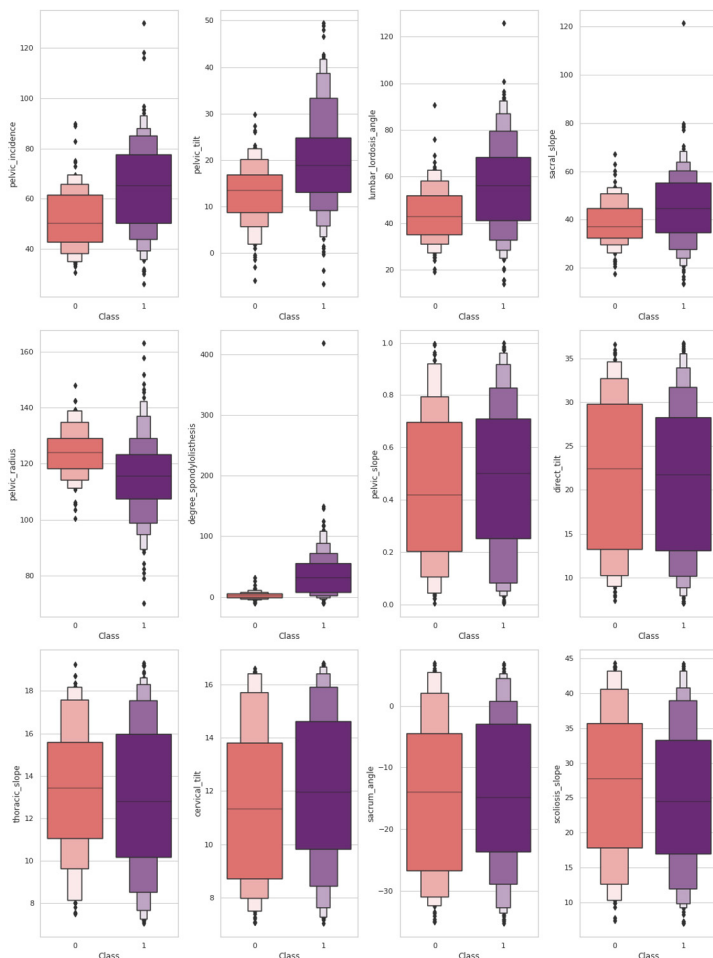


Figure 2. The linear correlation between variables

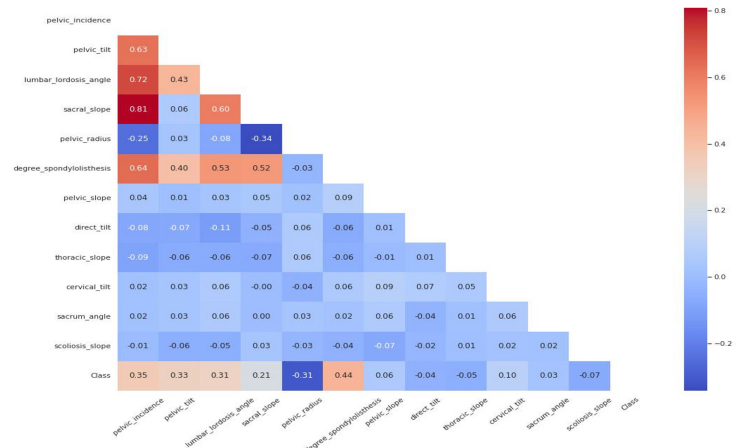


Figure 3. The heat map for correlation coefficient values in the dataset

The pairwise correlation coefficients between variables in the dataset are given in Figure 3. According to heat map, the values from -0.8 to 0.8 are represented with the color scale which changes from blue to red. This illustrates the magnitude and direction of the correlation between any two variable. In this figure, a positive correlation is demonstrated with red color whereas a negative correlation is with blue one. Additionally, lighter colors such as white, light blue, and light red represent weaker correlations. The correlation between *pelvic_incidence* and *sacral_slope* is 0.81, indicating a strong positive relationship. This implies that one rises along with the other. The variables *degree_spondylolisthesis* show moderate positive correlations with variables such as *pelvic_incidence* (0.64), *lumbar_lordosis_angle* (0.53), and *sacral_slope* (0.52). Moreover, the variable *pelvic_radius* has a negative correlation with *pelvic_incidence* (-0.25) and with *sacral_slope* (-0.34), respectively. This indicates an inverse relationship. The boxplot graphic is created to detect the outliers in the dataset, as shown in Figure 4.

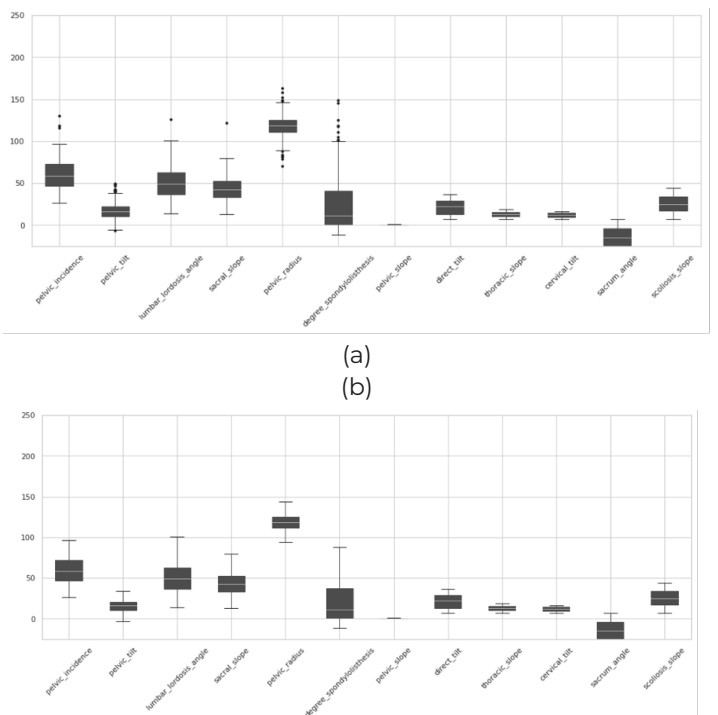


Figure 4. Outlier detection in the dataset (a) with outliers, and (b) without outliers

We used the Tukey method, a statistical approach, also known as Tukey's box plot method, to identify outliers in a dataset. It is based on the interquartile range. It also measures the spread of the middle 50% of the data. In Figure 4 (a), the outliers are detected. These outliers are adjusted by changing their median values for each variable, as in Figure 4 (b). The dataset contains features with remarkably varying magnitudes, units, and ranges. We performed z-score normalization to standardize the range of independent variables. Then, extreme gradient boosting (XGBoost) was applied to evaluate the importance of the variables.

The BG classifier, similar to RF, aggregated predictions from multiple trees but with variations in the training set to improve stability. To obtain the appropriate hyperparameter sets of these algorithms, we utilize a Grid Search optimization approach. This method systematically tests a range of hyper-parameters to determine the appropriate combination that maximizes the model performance. The classification algorithms with their hyper-parameter sets are given in Table 3.

Table 3
The classification algorithms and their hyper-parameter sets

Classifiers	Hyper-parameter Set	Range	Optimal Values Obtained Grid Search
RF	<i>n_estimators</i>	[50, 80, 100]	50
	<i>max_depth</i>	[4, 6, 8]	4
	<i>min_samples_split</i>	[50, 100, 150]	50
	<i>min_samples_leaf</i>	[40, 50]	40
	<i>criterion</i>	['gini', 'entropy']	<i>gini</i>
	<i>splitter</i>	['best', 'random']	<i>random</i>
ET	<i>max_depth</i>	[None, 10, 20, 30]	30
	<i>min_samples_split</i>	[2, 5, 10]	10
	<i>min_samples_leaf</i>	[1, 2, 4]	1
	<i>max_features</i>	[None, 'sqrt', 'log2']	<i>None</i>
GB	<i>n_estimators</i>	[5, 50]	250
	<i>max_depth</i>	[3, 5, 7]	7
	<i>learning_rate</i>	[0.01, 0.1]	0.1
XGB	<i>max_depth</i>	[1, 3, 5]	3
	<i>n_estimators</i>	[2, 5, 10]	5
	<i>learning_rate</i>	[0.01, 0.1, 0.5]	0.5
BG	<i>n_estimators</i>	[10, 50, 100, 200]	200
	<i>max_samples</i>	[0.5, 0.7, 1.0]	0.5
	<i>max_features</i>	[0.5, 0.7, 1.0]	1.0
	<i>bootstrap</i>	[True, False]	<i>True</i>
	<i>bootstrap_features</i>	[True, False]	<i>False</i>

Performance Evaluation

In this study, the diagnosis of spinal diseases is evaluated as a classification problem. Therefore, performance metrics related to evaluate a classification algorithm are utilized in order to determine the suitable model for the diagnosis of back pain symptoms. A confusion matrix demonstrate the performance of a classification model by laying out the actual versus predicted classifications in a tabular format. Using confusion matrix, the following performance metrics are calculated:

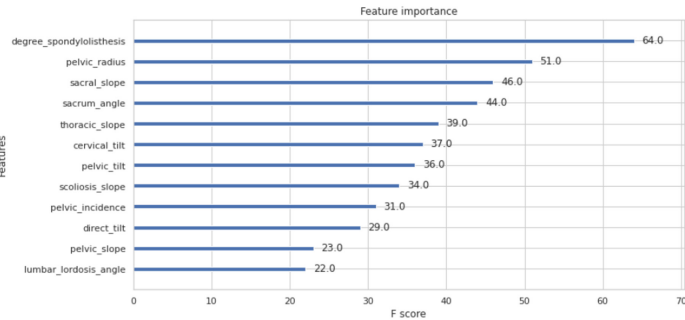


Figure 5. Evaluation of feature importance using XGBoost

In Figure 5, the x-axis represents the f-score values, and the y-axis lists the features used in the model. In XGBoost, the f-score values correspond to the feature importance weight values. A higher value indicates more frequent usage of the related feature in the model training phase. The most used feature for splitting the data in the XGBoost model is the *degree_spondylolisthesis* with the highest f-score (64.0) value. The high f scores for the subsequent *pelvic_radius* (51.0) and *sacral_slope* (46.0) indicate their important roles in the model. *lumbar-lordosis_angle* (22.0) is one of the lower scores. It indicates that while this feature contributes make a decision in the model, it does so less often compared to other features such as *degree_spondylolisthesis* or *pelvic_radius*.

Model Construction

In this study, we use a collection of ML algorithms to handle the classification problems, including Random Forest (RF), Gradient Boosting (GB), Extreme Gradient Boosting (XGB), Extra Tree (ET), and Bagging (BG) classifiers. RF and ET are ensemble learning methods that build multiple trees and averaging the results of each trees to provide final decision in order to suggests high accuracy and control over the overfitting issue (Breiman , 1996; Breiman, 2001; Friedman, 2001; Chen & Guestrin, 2016; Geurts et al., 2006). GB and XGB, on the other hand, sequentially build trees where each subsequent tree aims to correct the errors of its predecessor to enhance prediction results in each step.

Performance Metric	Definition	Equation
Accuracy	the ratio of correctly predicted observations to the total observations	$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$
Precision	assesses the model's accuracy among positive identifications	$Precision = \frac{TP}{TP + FP}$
Recall	measures the model's ability to detect actual positives from the data	$Recall = \frac{TP}{TP + FN}$
F_score	the harmonic mean of precision and recall	$F_score = 2 \times \frac{Precision \times Recall}{Precision + Recall}$

Receiver Operating Characteristic (ROC) curve plots the true positive rate (recall) against the false positive rate ($FPR = \frac{FP}{FP+TN}$), providing a graphical representation of a model's diagnostic ability.

RESULTS

This study was conducted on a computer equipped with a Windows 10 Pro 64-bit operating system and an Intel(R) Core(TM) i7-10750H CPU @ 2.60GHz, which operates at a speed of 2.59 GHz. The system utilizes a 64-bit processor architecture and has 31.8

The area under the ROC curve (AUC) quantifies the overall ability of the model to discriminate between the classes across all thresholds, with 1 representing accurate discrimination and 0.5 denoting no discrimination.

GB of available memory (RAM). For the development, coding, and testing of applications, we utilized the Jupyter Notebook as our editor, along with the Python programming language. The test results of the algorithm are given in Table 4.

Table 4
Test results of the classification algorithms using training dataset

Classifier	Train Accuracy	Test Accuracy	Train ROC	Test ROC	Precision	Recall	F-score
RF	0.818	0.694	0.904	0.819	0.745	0.864	0.800
ET	0.899	0.871	0.971	0.899	0.950	0.864	0.905
GB	0.996	0.774	1.000	0.879	0.841	0.841	0.841
XGB	0.943	0.774	0.985	0.879	0.841	0.841	0.841
BG	0.976	0.806	0.997	0.867	0.848	0.886	0.867

In healthcare data, it is possible to encounter imbalanced class distributions where the number of samples in one class is higher than in the other class. For imbalanced datasets, accuracy may not be an appropriate metric since it is a ratio of correctly predicted observations to the total observations. Therefore, the proportionate representation of each class may not be taken into consideration by the accuracy metric. In a situation where one class significantly outnumbers the other, the model may have a very high accuracy bias against the majority class. Thus, it will be insufficient to accurately predict the data in the minority class. It is more appropriate to utilize a balanced metric in terms of precision and recall in such situations. Since the F-score is the harmonic mean of precision and recall, it is used to determine the most efficient classification model where there is a remarkable difference in terms of the number of instances between classes. In this study, the "Abnormal" class has more samples than the "Normal" class. According to Figure 1, there are 210 instances in Class 1 ("Abnormal") and 100 instances in Class 0 ("Normal"). In such cases, the machine learning model may achieve high accuracy by dominantly predicting the majority class while failing to correctly identify the minority class, which can lead to critical results in medical diagnoses. Therefore, using

the f-score performance metric is a more appropriate approach for model evaluation. Thus, for diagnosing lower back pain using imbalanced datasets, a classifier that achieves the highest F-score is considered the most suitable algorithm, as it ensures a more reliable and balanced performance across the different classes. According to test results in Table 4, the BG classification algorithm, validated with the highest f-score value, proves to be an appropriate selection for smart healthcare systems aimed at diagnosing lower back pain. The ET algorithm closely follows the BG algorithm, demonstrating high performance values. The results of the study demonstrate the effectiveness of ML algorithms in diagnosing lower back pain. Based on the experimental results, the BG classification algorithm outperforms the other algorithms in diagnosing lower back pain. While this study demonstrates the potential of ML models, such as BG and ET, in diagnosing lower back pain, there are certain limitations. The model proposed in the study and the dataset used in the study consist of 310 observations obtained from a limited number of sources and a single source. This may limit the generalizability of the models. The models were tested only with the dataset used in this study. Failure to validate their performance in different datasets or real clinical settings may create

a limitation in terms of generalizability of the results. This study highlights the potential for AI to enhance accuracy while supporting early detection in medical diagnostics. The study contributes to the growing body of research on utilizing artificial intelligence technologies for early diagnosis in spinal disorders among adolescents.

CONCLUSIONS

Spinal disorders are becoming more common in young people due to a variety of factors such as poor sitting posture, long-term posture fatigue, and regular use of electronic devices. This leads to pain and distress caused by lower back problems. Lower back pain problems not only cause pain, but they also make life difficult. It is very important to detect lower back pain at an early stage, as AI tends to prevent the deterioration of lower back pain into the older ages by diagnosing it at an earlier age. The use of AI is aimed at assisting specialists in this study. For this purpose, various ML algorithms are compared to determine the most efficient algorithm to diagnose spine problems using the publicly available dataset.

For this purpose, various ML algorithms, including RF, GB, XGB, ET, and BG, are compared to identify the most efficient algorithm for diagnosing spinal problems using the publicly available dataset. The study highlights the importance of hyper-parameter optimization to achieve the best performance for each model. According to the experimental results, the BG classification algorithm performs better in diagnosing lower back pain when compared to other algorithms. Experimental results demonstrate the potential of ML algorithms for early diagnosis of spine diseases in adolescents. These findings not only highlight the predictive accuracy of these algorithms but also point to their practical applicability in healthcare systems. The proposed method leverages the strengths of ensemble learning to improve diagnostic accuracy and reliability. The findings of this study highlight the potential of AI to increase disease diagnosis accuracy and support early detection in diagnosing spinal diseases in adolescents.

In future work, it is planned to integrate various publicly available dataset to determine the robust ML learning framework to detect spinal disease in an early stage to help experts in this area. Additionally, the features are analysed in depth to interpret the nature of the problem. Future studies will also focus on developing more interpretable models using explainable artificial intelligence (XAI) techniques. These models aim to provide experts with not only accurate predictions but also clear insights into the decision-making process. Thus, it aims to increase trust and facilitate the adoption of AI in clinical practice.

Conflict of interests

The authors declare no conflict of interest.

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USER BEHAVIOR ANALYSIS OVER A DYNAMIC IMPLEMENTED ZERO TRUST NETWORK ARCHITECTURE

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Abstract

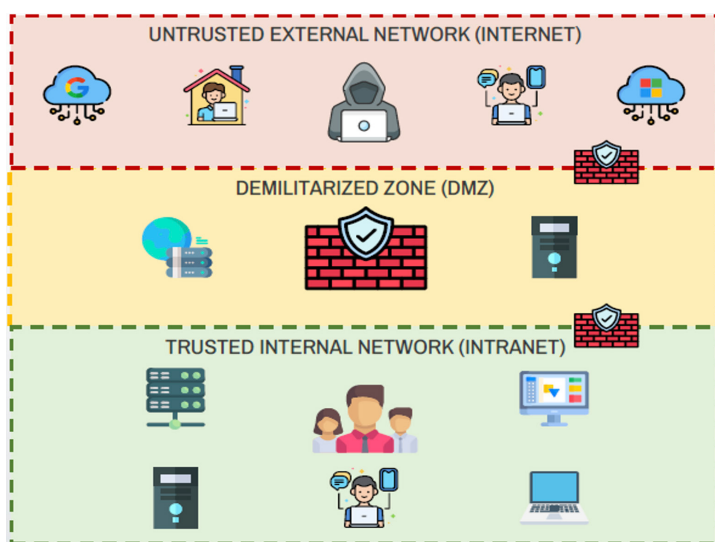
The dynamics of the ever-evolving threat landscape in the world of cyber keep advancing at such a speed that it is crucial for the organizations to adopt innovative security frameworks. However, the question that arises is how accessible are these frameworks for the organizations? This paper aims to highlight the importance of implementing a Zero Trust Network Architecture as a means to address all these security challenges, in a way that can be accessible for every organization regardless of size and without any significant financial constraint. While previous research examines the ZTNA framework and its applications, alongside there are other studies about User Behavior Analysis and its implications in cybersecurity focusing on theoretical aspects of each. Nevertheless, the solution this paper presents, incorporates both of them into a practical implementation that aims to improve organizational security posture. Yet, how will be reduced such an attack surface, with the risk posed not only on the outside perimeter but as well as by their own employees? By leveraging machine learning algorithms, we aspire to demonstrate that a robust tool fed by ZTNA logs could be created providing real-time threat detection and automated response mechanisms thereby reducing the possibility of lateral movement inside the infrastructure and colossal damage or theft of data and accesses. It comprises the usage of solely open-source tools avoiding vendor lock-in and allowing more flexibility and accessibility on integration of various technologies. Key findings recommend constantly updating baseline profile for accuracy in anomaly detection. The research illustrates that comprehensive security measures are achievable for all organizations, ensuring enhanced protection in today's dynamic network environments.

Keywords: Zero Trust Network Architecture (ZTNA), Dynamic Framework, Cybersecurity Challenges, Machine Learning Algorithms, Threat Intelligence, Continuous Authentication

INTRODUCTION

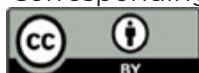
In recent years, the cybersecurity landscape has witnessed a rise in sophisticated attacks targeting organizations worldwide. It is particularly alarming to note the rise in insider threats, in which workers or other authorized personnel inadvertently or purposely jeopardize data security. Based on the statistics from the Data Exposure Report (DER), one in three data breaches are caused by insider activity, counting an average of \$16 million annual financial loss per incident. (Code 42's, 2023) Considering the fact that insiders can jump off the security measures designed for the outsiders not to break in the system, it becomes challenging to identify these actors and stop their actions. According to the Cost of Insider Threats report, it will take an estimated 85 days to suppress the threat. This makes insider threats particularly difficult to counter. The longer duration not only increases organizational costs but also complicates the containment process because more resources have to be dedicated to handling these situations. Marking digital transformation as the main catalyst, there are a number of additional variables that make today's infrastructure and network architecture vulnerable to these threats. IT infrastructure used to be composed of a firewall-protected trustworthy internal network (intranet) and an untrusted external network

(internet) as depicted in Figure 1. But as technology developed, this boundary became increasingly hazy with the emergence of DMZs for services that are visible to the public, such as websites.



1. Traditional Network Perimeter (Alton Teaches-Udemy Course ZTNA Principles)

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Moreover, as employees started accessing their company internal network from several different locations and devices, lines were slowly blurring where concepts like remote work and BYOD became the new trend. Zippia, the career expert, conducted a survey and stated that 83% of businesses had brought in bring your own device (BYOD) rules by 2023, permitting employees to use their own devices on company networks. The old concept of the trust boundary was eroded daily, as the evidence brings up the observations that 8 out of 10 people now work remotely or have hybrid schedules, based on a 2023 Gallup survey.

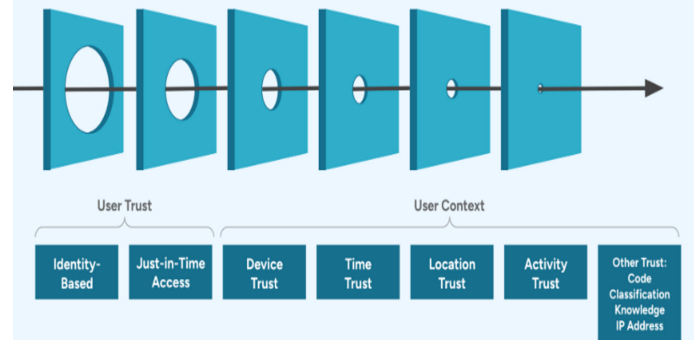
Observing the existing infrastructure of most of the enterprises and how they manage remote connection for client applications or employee access, it results that 72% of them use VPN connections. (Nicoletti, 2022) VPN's pose greater risk to the organization, giving unlimited access to the whole network once a user is successfully authenticated. Only with some user credentials and the VPN tunnel a hacker can bypass the access and get sensitive information of the company and the hosts in the network, especially with the advancement of tools and quantum computers that in a matter of seconds can break in the encryption used.

As a result of the growing adoption of cloud services, most of the resources considered as critical for the organization were scattered around the internet not sticking to the old network defined perimeters. According to a 2021 O'Reilly poll, almost 90% of the enterprises had embraced cloud and used their services for hosting the applications and managing their infrastructures. Consequently, the conventional notion of the trust perimeter inside of an on-premise infrastructure vanished, indicating the necessity to transition to a new paradigm. Considering these facts organizations would start to develop a new perspective on treating their environment as hostile and giving up from an implicit level of trust inside their perimeters. They would tentatively need a granular access control mechanism and a proactive approach to threat detection and response. Coming up to these needs of the organizations nowadays, there is a set of principals building upon a whole framework architecture called Zero Trust Network Architecture. In response to this changing threat scenario, following the Zero Trust Network Architecture (ZTNA) model by organizations has emerged as a critical technique for improving security posture. Furthermore, as per Twilio's COVID-19 digital engagement report, the pandemic accelerated digital transformation by six years, outpacing Moore's Law. This acceleration highlights the necessity of adopting the Zero Trust model in order to keep up with the ever-changing digital landscape.

Still, the question is what makes this model a framework to follow and enhance the security of our organization? Well, ZTNA is not a singular technology, it's more of a philosophy and a mindset. It operates on the premise of a hostile environment, treating both internal and external threats with equal vigilance and disregarding network locality as a trust determinant, emphasizing dynamic, context-based access policies. These policies

are based on some foundational component called attribute-based access controls that differently from role-based access controls examine data such as time, location, authentication history, device settings, IP address, and communication type, providing a more sophisticated approach on determining dynamically the access a user must have on several components of the network.

Context narrows the aperture for access & decreases risk



2. Kipling methodology for developing ZTA policies (Michaline Todd, StrongDM)

In order to develop robust access policies regarding these attributes, in alignment with ZTNA tenets for the identities of employees or system users in any kind of role they have, organizations use techniques like the Kipling Method, as in Figure 2. ZTNA architectural approach views trust as a vulnerability in information security, asserting that relying on the reliability or integrity of someone or something is inherently unpredictable due to its behavioral nature. (Edo, 2022) Consequently, ZTNA adheres to the principle of "Never Trust, Always Verify" while concurrently ensuring individuals receive precisely tailored access, precisely when and where it is needed—no more, no less.

The goal of this paper is to emphasize the importance of implementing Zero Trust Network Architecture for organizations in this era where the actual conditions of the network infrastructure have changed notably and the necessity for reducing the attack surface is great. However, while the practical benefits of ZTNA are increasingly evident, several challenges remain. Based on the cost-benefit analysis of Zero Trust and Behavior Analytics, the implementation of this framework involves significant costs. (Sharma, 2021). But, how can this be embraced by the organizations wishing to improve their organizational security? By implementing a ZTNA model only by using open-source and vendor-neutral tools we aspire to demonstrate that organizations of all sizes can afford and benefit from this robust security framework. The accessibility of this process makes it feasible for even smaller organizations with limited resources to enhance their security posture effectively. Moreover, the automation of this implementation further simplifies the process, reducing manual effort and ensuring consistent, reliable deployment. Nonetheless, the question that

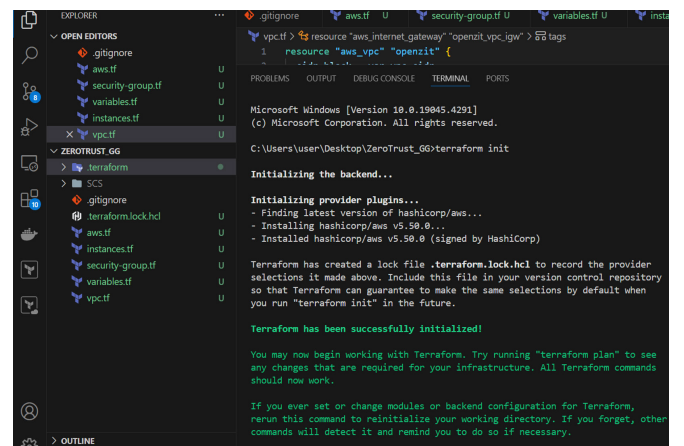
emerges is how scalable is this framework when applied to high-demand network environments? The novelty that we bring is the integration of a machine learning algorithm to analyze user behavior and detect threats in real-time from the logs of the implemented ZTNA architecture adopting to its dynamic nature. This approach leverages advanced analytics to identify and mitigate potential security incidents, enhancing the overall efficacy of the ZTNA framework. Sharma in his research about theoretical implications of the integration of Behavior Analysis to ZTNA, underscores the importance of the baseline profile to achieve desired results in anomaly detection. Still, it falls short in exploring real-time adaptability to evolving user behaviors. This gap is crucial since static baselines may miss nuanced threats in dynamic environments. Addressing this gap, our research will contribute to an adaptive, machine learning-driven behavioral model that continuously updates in response to real-time data. This approach aims to reduce false positives and negatives, enhancing the accuracy and responsiveness of threat detection within ZTNA. This research will illustrate that a comprehensive security approach is achievable for all, regardless of budget or technical expertise, underscoring the practicality and necessity of adopting ZTNA in today's dynamic network environment.

METHODS AND TOOLS

The tools that will be used in this implementation include Terraform for script automation and ease of infrastructure deployment, AWS for infrastructure hosting and VM creation, Open Ziti for applying the Zero Trust principles directly as a tunneler for our application, Docker for the images processed for our web application Odoo Erp, portainer image for having a clear view of the controllers, routers and the state of them, as well as the Ziti Admin Console Interface, Python Libraries and Machine Learning algorithm to detect anomalies in real time for threat detection, Slack for Alert Notifications.

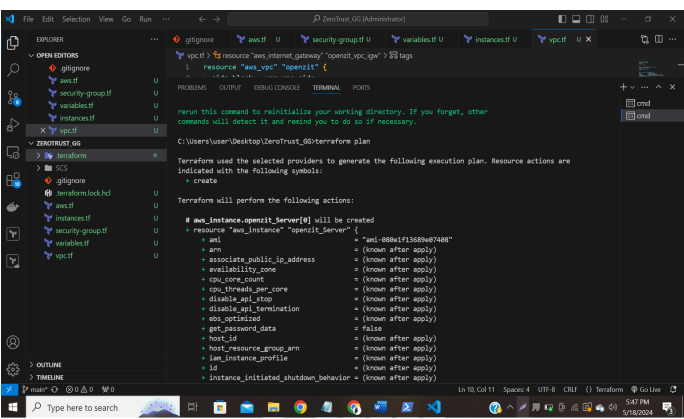
2.1 Creating Infrastructure

The first implementation phase consists of creating the infrastructure needed to deploy this application and embed Zero Trust. The provider we chose to host our Virtual Machines was AWS cloud environment. For creating our VMs that are needed for the web application hosting and openziti servers we continued with an automated solution and create all these VMs all at once with Terraform.



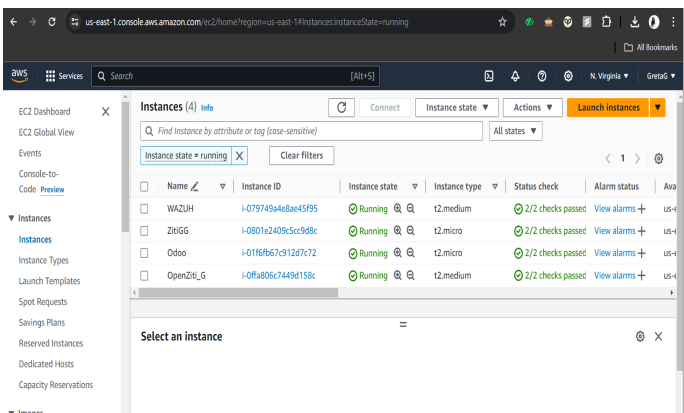
3. Terraform Initialization

After preparing some configuration scripts that detail all the information about the three machines creation including some access and private keys configured in the Key Pair Section in AWS for each service, we initialize Terraform, which prepares the environment for us and downloads all the plugins needed to interact with AWS services. Additionally, it creates a lock file to keep record for the versions of plugins used therefore maintaining consistency for all future runs and promoting reproducibility.



4. Terraform Planning

Proceeding with the planning step after successful initializing terraform, we prepare the scripts for creating 3 VM's all at once, with all configurations predefined. We execute the terraform plan command that starts reading and evaluating all the config files provided and creating an execution plan for them. This way terraform will perform the actions that are planned to achieve the state of infrastructure as we have configured. Additionally, the scripts prepared install docker on every machine automatically without the need to run installation commands one by one in the terminal repetitively for each instance. After application of all these files with the apply command and terraform finishing, we have resources added in our elastic compute dashboard and instances running.



5. AWS Dashboard & Instances Running

Therefore, we finish with the first step of the implementation phase, where it is demonstrated the efficiency of creating our infrastructure through powerful terraform scripting that allows you to automate the process and write scripts in a declarative way, where you explain how the infrastructure should look like.

2.2 Openziti Configuration

In the second implementation step we focus on configuring OpenZiti environment in order to bring all Zero-Trust principles together in one place. There are several opportunities for setting up OpenZiti and we chose the option that can come in handy for several different cases on which the organization want to set up their network. The case is 'Host OpenZiti Anywhere' that is offered by the Ziti Team with the command of express install and is all opensource. We carry on the process by initializing some variables about the ports where the controller and router will be set up as well as the external public DNS of the instance in AWS where we will set up the OpenZiti 'ec2-100-25-159-180.compute-1.amazonaws.com'. Then executing the command provided in OpenZiti documentation we install all the components needed:

```
source /dev/stdin <<< "$(wget -qO- https://get.openziti.io/ziti-cli-functions.sh)";
expressInstall
```

After this step we verify that the main controller and router are running and active as in the image highlighted below.

```
ziti-controller.service - Ziti-Controller
Loaded: loaded (/etc/systemd/system/ziti-controller.service; enabled; vendor preset: enabled)
Active: active (running) since Thu 2024-06-13 12:37:00 UTC; 5min ago
Main PID: 53821 (ziti)
Tasks: 7 (limit: 4666)
Memory: 60.7M
CPU: 2.547s
CGroup: /system.slice/ziti-controller.service
└─53821 /home/ubuntu/.ziti/quickstart/ip-172-31-53-61/ziti-bin/ziti-v1.1.3/ziti contro

ziti-router.service - Ziti-Router for ip-172-31-53-61-edge-router
Loaded: loaded (/etc/systemd/system/ziti-router.service; enabled; vendor preset: enabled)
Active: active (running) since Thu 2024-06-13 12:36:17 UTC; 6min ago
Main PID: 53411 (ziti)
Tasks: 7 (limit: 4666)
Memory: 18.7M
CPU: 2.740s
CGroup: /system.slice/ziti-router.service
└─53411 /home/ubuntu/.ziti/quickstart/ip-172-31-53-61/ziti-bin/ziti-v1.1.3/ziti router

ubuntu@ip-172-31-53-61:~$
```

6. Controller & Router Status

In order to have an easier way of managing, creating and accessing these routers we can install also the Ziti Admin Console (ZAC) interface that facilitates the process.

Commands used for this:

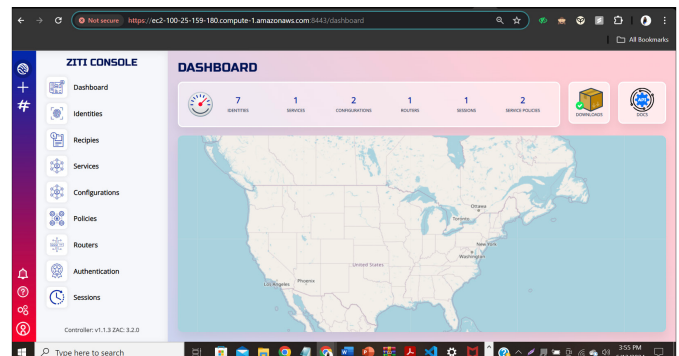
```
sudo apt install nodejs npm -y
sudo npm install -g @angular/cli@16
git clone https://github.com/openziti/ziti-console.git "${ZITI_HOME}/ziti-console"
ng build ziti-console-lib node
```

To open the ZAC in a web browser and manage from the interface we need to associate some certificates for this console and we use these commands to do so:

```
ln -s "${ZITI_PKI}/${ZITI_CTRL_EDGE_NAME}-intermediate/certs/${ZITI_CTRL_EDGE_ADVERTISED_ADDRESS}-server.chain.pem" "${ZITI_HOME}/ziti-console/server.chain.pem"

ln -s "${ZITI_PKI}/${ZITI_CTRL_EDGE_NAME}-intermediate/keys/${ZITI_CTRL_EDGE_ADVERTISED_ADDRESS}-server.key" "${ZITI_HOME}/ziti-console/server.key"
```

By doing this we have self-signed certificate assigned to our Ziti Console. This architecture of communication through the Ziti Components but not only, is done also through these certificates using mutual TLS that are used for authentication on both sides of the communication, both parties.



7. Ziti Admin Console Successfully Set Up

Every client should have a client certificate through which it is authenticated and authorized as an identity, that is then checked within Ziti Network if it has access to any application the client is requesting access upon. When successfully checked, all the open ports in the network are closed to ensure that zero access to any open hole in the network is given to the identity, except that of the own application or applications though this identity may have multiple.

2.3 Identities & Services Creation

Coming to the identities in OpenZiti they represent the users that will go through the network filtering of the attribute policies that will be built upon them in order to access the services they need. In order to create identities we used some cli commands but they can be easily created in the interface of ZAC

```
ziti edge create identity user windowsweb -o windowsweb.jwt
ziti edge create identity device ubuvm -o ubuvm.jwt
```

With these commands we created two identities one for the client and one for the server, saving their Json Web Token (JWT) that will be used for authenticating both of the parties. Then we configure our specific network endpoint that will be used for the Odoo service that we will setup on port 8069 with a TCP protocol. The intercept configuration specifies how the traffic to the Odoo service will be handled.

```
ziti edge create config odoo-host.v1 host.v1 '{"protocol": "tcp", "address": "odoo", "port": 8069}'
```

```
ziti edge create config odoo-intercept.v1 intercept.v1 '{"protocols": ["tcp"], "addresses": ["odoo.ziti"], "portRanges": [{"low": 8069, "high": 8069}]}'
```

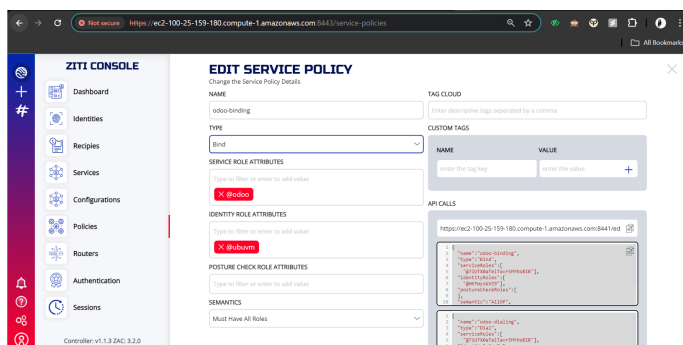
Having the configurations ready we create our service, Odoo and associate with the particular configurations from above. Therefore, service tells the edge router how to handle connections to Odoo Service.

```
ziti edge create service odoo --configs "odoo-
intercept.v1" , "odoo-host.v1"
```

Managing the access to this service created we should also provide configurations for the service access policies. We create two access policies: one that will be used to bind the service Odoo to the Ziti network overlay which will be done from the identity ubuvm that we created before and the other policy that specifies which identity will be allowed to initiate connections to the Odoo service.

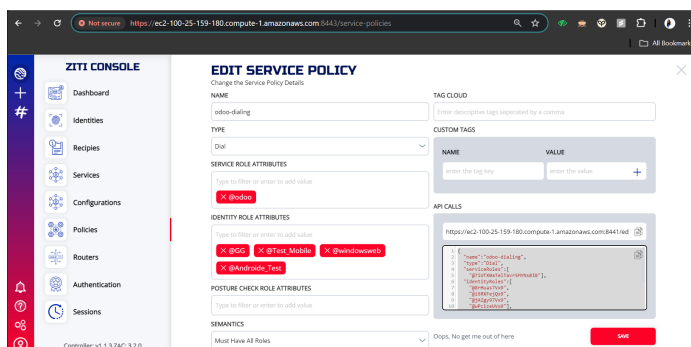
```
ziti edge create service-policy odoo-binding
Bind --service-roles '@odoo' --identity-roles
'@ubuvm'
```

```
ziti edge create service-policy odoo-dialing
Dial --service-roles '@odoo' --identity-roles
'@window sweb'
```



8. Bind Service Policy

End here we can see them created in the interface. For the dial service policy we have added some other identity users, created from the ZAC console that will have access to dial to the Odoo Service.



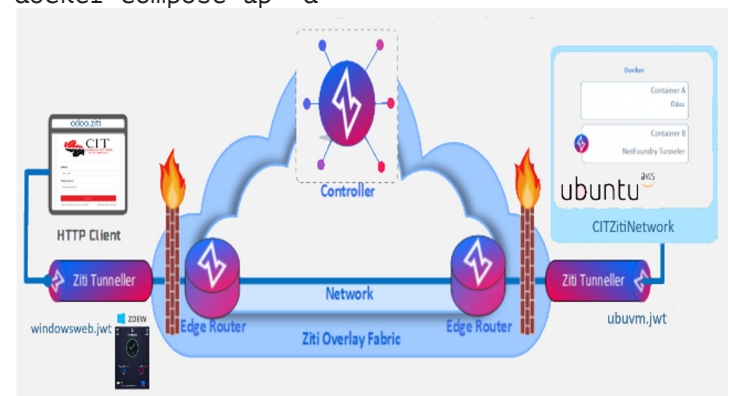
9. Dial Service Policy

2.4 Server Odoo Set Up

In this implementation step we continue with the creation of the real service that will be connected with OpenZiti. In our case, I decided to set up Odoo which is an open-source ERP that in recent years have gained popularity, especially here in Albania and is being used by most of the companies for internal management. However, every organization can follow these steps for whatever service they want to 'zitiify', in our case a web-application.

Firstly, we create a virtual network that will serve as a bridge communication between the ziti-edge-tunneller and the web application. Then, we prepare a configuration file docker-compose which contains the images of Odoo:17 and Postgres:15 that are needed to set up this web-application.

```
docker network create CITZitiNetwork
docker-compose up -d
```



10. Architecture of Communication (Adapted from Openziti Official Documentation Website)

When the container is created, Docker creates as a default network the one with the same name as the container. We disconnect from that default network and connect to the network we created, to make sure that Odoo container communicates only through this specified network CITZitiNetwork.

```
docker network disconnect default odoo
```

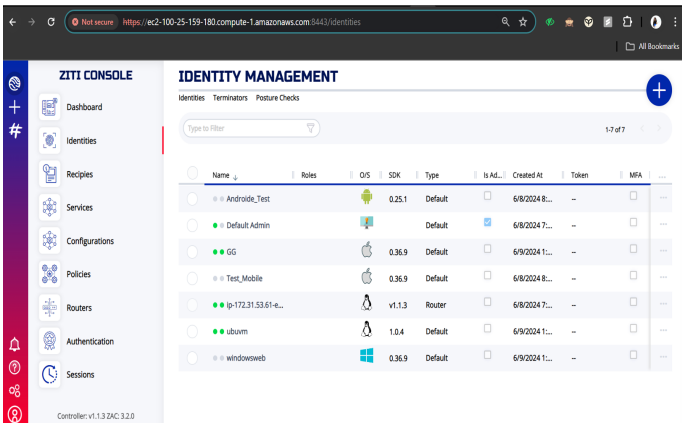
```
docker network connect CITZitiNetwork odoo
```

Continuing, it is time to create and install the docker container for the tunneller inside the web server and bind it to the ubuvm identity that we have created before. This will be as an offload point for the traffic that will be delivered to our Odoo web-application. We will create it in the same network as the Odoo container in order to communicate through that overlay.

```
docker run \
--rm \
--network CITZitiNetwork \
--network-alias zet \
--name ziti-edge-tunnel \
--volume ~/.ziti/ids:/ziti-edge-tunnel \
--env=Nf_REG_NAME=ubuvm \
openziti/ziti-edge-tunnel:latest run-host
```

2.5 Identities Enrollment

For testing the communication between client and server through the Ziti Overlay Network, we have created 3 different identities. One will be tested with the Ziti Mobile Edge in IOS Phone, another in Android Phone and one in Windows with Ziti Desktop Edge. These three tunnellers will enable each of the identities enrollment and according to the particular configurations will be defined if they will access the service or not. We firstly have the windowsweb identity that we created before from the command line and assigned policies, giving access for the service Odoo. We access the token from the identity dashboard and download the One Time Token through which this identity can be enrolled and upload it in the ZDEW where we successfully enroll it. This Json Web Token has expiration and is not available for much time, so you should enroll this identity during the defined timestamp. It is for one time only so you make sure that no one else uses that for enrollment even if it has gained access to.



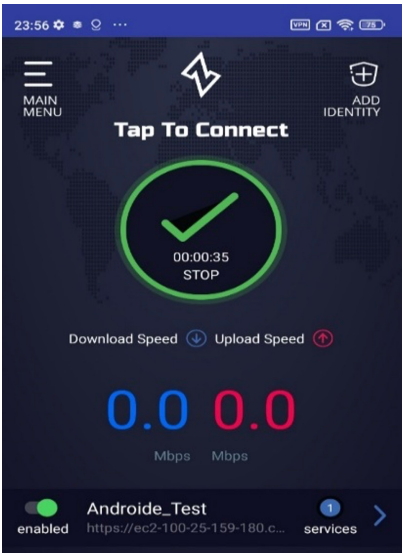
11. Identities Dashboard

If we decide at any point to forget this identity, and try to enroll again with the same JWT it will fail, because one identity is only for one device and for one time enrollment. No one else can use your identity this way minimizing the attack surface for unidentified users to access the service. Then, if any unauthorized user has access to your device and can connect through Ziti Desktop Edge, it is part of log monitoring to identify this occurrence through user behavior analysis for any anomaly activity throughout the service. However, even if this happens, the way Ziti Overlay Network is built upon, they have no chance to access other parts of network and make any kind of lateral movement, except from the applications that they have access to. Only those ports are open for that identity. This is why each identity is configured in that way with the least privileges as possible just in time and just enough access as he needs to do his tasks. When you may have identified an anomaly from that identity client, you can just remove the access policy for the services. So, the damage is minimized immediately.



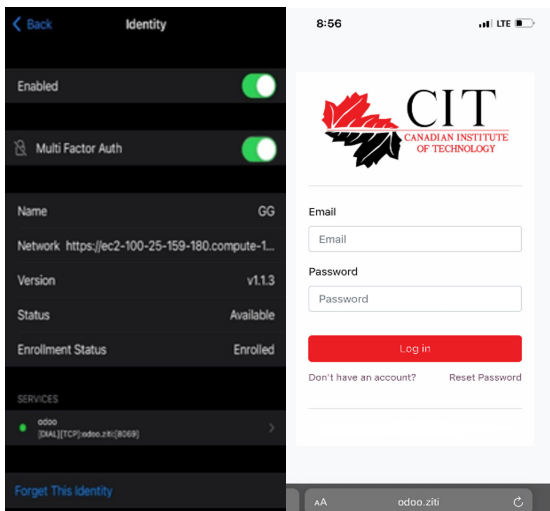
12. Identity Enrollment with QR Code

For the other use cases it will be easier to do the enrollment via QR code and scanning from the phone.



13. Successful Enrollment of Androide_Test identity Android Device

The third use case is the identity enrollment from the IOs Device. In terms of our architecture the process starts from the identity GG that dials the odoo. ziti website at port 8069. In the overlay network we have the ziti tunneller that intercepts this request and send it to the Ziti Overlay Fabric. Here the identity is authenticated and checked for access policies towards that service that has requested upon. Then, the intercept packet is delivered to the target identity, which is binded to the web-server where Odoo service is hosted.



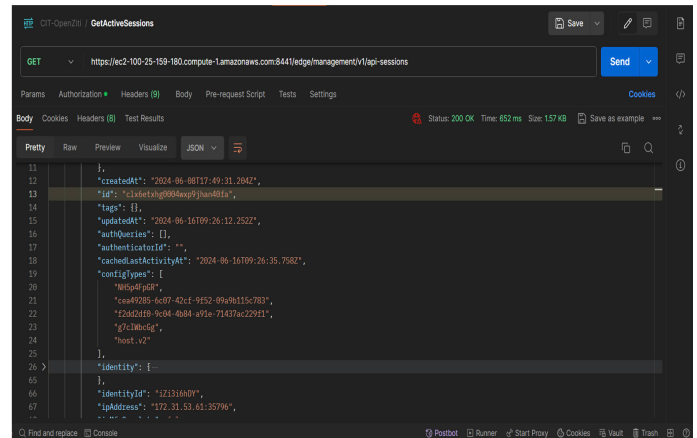
14. Successful Enrollment of GG Identity from IOs Device and access to the Odoo Service

2.6 Log Collection

Identifying the possibilities of collecting logs from the OpenZiti, we have controller logs and router logs that are real time processed. However, the information I need for possibly detecting any suspicious activity, analysing the user behavior and threat analysis, would be to take information on the active sessions in real-time. This would be better to analyse as we have the time this session was created, was updated as well as the IP address coming from. For collecting these logs, since they are not saved in any specific path inside the ziti directory, we need to retrieve them by using some API calls on the specific endpoints to get information on the active sessions. We started by building up a Postman Collection in order to be able firstly to retrieve these data. The specific endpoint we need is this:

```
{public-url}/edge/management/v1/  
api-sessions
```

While building the right call to the endpoint, we should make sure to put the authentication method that in our case should be an API Key that is the token from the zitiLogin command in the controller where we login from the CLI. It should have the key as zt-session and the value of token. After specifying this parameter that should be added in the header we now send a Get Request to the specific endpoint getting in real time the active sessions and all the information generated for each specific one. Here is depicted as well in the image the postman request we made and the response body we got. As we can see from the response, we have all the information when a session is created, updated, when was the last activity, the IP address connected from and other specific information that we can use to detect any anomaly in these sessions and possibly track any threat. This request needs to be executed in real time in order to get the latest information on session creation.



15. Postman Request for Getting Active Sessions

Therefore, we created a scheduled function in python to run every minute in order to get the latest active sessions. This function consists of an API call, built using python libraries. The issue here for us as developers, would be the token of authorization to execute this API call because it is not always the same but it changes during a short timeframe, whereas per security it is an added value to what is pointed. We will create also an automated process to get this token, where the way this token is retrieved is by executing two commands in CLI, one for setting up the environment with all needed variables and one for login to ziti which is the command that provides the token for us to use. In order to achieve the desired results we will have an executable file that will be created in the directory as our python code. This executable file 'get_ziti_token.sh' will contain these lines of code:

```
#!/bin/bash  
~/ziti/quickstart/${hostname -s}/${hostname  
-s}.env  
zitiLogin
```

The python code we build will go and execute this file through the subprocess library. And take the output that is the Token. The request that is sent by postman, we will build in python in order to execute it automatically and get the result data continuously to check for threats in real time. This function uses the library request of python to send a GET request to the specified URL and with a parameter for the token that will be provided from the get_token function specified above.

This function returns the JSON data same as in the postman response body that we will then preprocess to fetch only the data that we need.

```
def get_token():
    try:
        # Run the shell script to source the environment and get the token
        result = subprocess.run(['./get_ziti_token.sh'], capture_output=True,
                                text=True, shell=True, executable='/bin/bash')
        token_line = [line for line in result.stdout.split('\n') if 'Token:' in line]
        if token_line:
            token = token_line[0].split('Token: ')[1]
            return token.strip()
        else:
            print(f"Error in getting token: {result.stderr}")
            return None
    except Exception as err:
        print(f"An error occurred while retrieving token: {err}")
        return None
```

16. Function to get the dynamically generated token in order to execute API

Here a suppress for the Insecure is added just in our case where we have a self-signed certificate because for demonstration purposes we have not bought a domain and applied a certificate from a certificate authority, that's why in the function we have also verify False.

```
import subprocess
import requests
import urllib3

URL = "https://ec2-180-25-159-180.compute-1.amazonaws.com:8441/edge/management/v1/api-sessions"
urllib3.disable_warnings(urllib3.exceptions.InsecureRequestWarning)

def get_active_sessions(token):
    headers = {
        "Content-Type": "application/json",
        "zt-session": token
    }
    try:
        response = requests.get(URL, headers=headers, verify=False)
        response.raise_for_status()
        return response.json()
    except requests.exceptions.HTTPError as http_err:
        print(f"HTTP error occurred: {http_err}")
    except Exception as err:
        print(f"An error occurred: {err}")
    return None
```

17. API Call for collecting the information from the active sessions

```
def parse_sessions(data):
    records = []
    for session in data['data']:
        record = {
            'createdAt': session['createdAt'],
            'updatedAt': session['updatedAt'],
            'cachedLastActivityAt': session['cachedLastActivityAt'],
            'identityId': session['identityId'],
            'ipAddress': session['ipAddress'].split(':')[0],
            'name': session['identity']['name']
        }
        records.append(record)
    return pd.DataFrame(records)

def add_features(df):
    df['createdAt'] = pd.to_datetime(df['createdAt'])
    df['updatedAt'] = pd.to_datetime(df['updatedAt'])
    df['cachedLastActivityAt'] = pd.to_datetime(df['cachedLastActivityAt'])
    df['hour'] = df['createdAt'].dt.hour
    df['country_name'] = df['ipAddress'].apply(get_country)
    df['country'] = pd.factorize(df['country_name'])[0]
    return df
```

18. Function to process the data for extracting the information we need

We need to apply another function for this and we will integrate a communication with IPInfo that through a token that we will have, we can integrate with their system for accessing the geolocation of the IP Address that we will provide from the processed data. Below is the function used to get the country name in this platform of checking the geolocation.

```
# Initialize IPinfo handler
ipinfo_handler = ipinfo.getHandler(iptoken)

def get_country(ip):
    try:
        details = ipinfo_handler.getDetails(ip)
        return details.country_name
    except:
        return 'Unknown'
```

19. Retrieving information on the country where the IP is located

2.7 Log Preprocessing

In this implementation phase, we focus on extracting the data that we are interested for in order to do analysis over them and convert into a more readable and easier way to manipulate. For this we will use the pandas library to convert our json data into DataFrames that are easier to read and manipulate. As it is depicted in the code these two functions use the pandas library that is pd and takes all the necessary data from the JSON response offered by the API, and converts them into DataFrame. The 'add_features' function is part of the Feature Engineering where we manipulate those data as we wish for having them. In our case, we convert into datetime all the objects representing a time data as well as adds some information helpful, for example we need the hour of accessing the Ziti Overlay Network and creating a session despite the date, as well as the country where the IP is located to.

2.8 Model Training

For training a model we will use data registered from previous days or months, as longer as it is the timestamp the more data for building up a model would be and the more accurate the model will result for our anomaly detection. Firstly we prepare these data that will be in a json format and will serve as a parameter for processing these data and extracting what is needed.

```
# Preprocess historical data
historical_data = preprocess_data(df)

# Convert categorical country data to numerical data
historical_data['country'] = pd.factorize(historical_data['country'])[0]

# Features for model training
features = historical_data[['hour', 'country']]

# Train Isolation Forest model
baseline_model = IsolationForest(contamination=0.1)
baseline_model.fit(features)

# Save the model for later use
with open('baseline_model.pkl', 'wb') as file:
    pickle.dump(baseline_model, file)

print("Baseline model trained and saved successfully.")
```

20. Model Training and Baseline Creation

We convert the country data that is categorial into numerical one by factorizing using pandas and then we create an Isolation Forest Model with a contamination rate of 10%, which is the proportion of outliers in the data that is converted into DataFrames. With the fit method of Isolation Forest we train the model using the features DataFrame. This model learns the patterns of a normal behavior based on two features, particularly with the hour of session creation and the country logged in.

We save this trained model in a file, in write-binary mode and put the serialized object of the baseline_model in order to use it for prediction of threats.

2.9 Detecting anomalies & alerting

Detecting anomalies will be done by comparing all the data retrieved from the API call that is executed every 10 minutes with the baseline model created before.

```
def job():
    print("Fetching active sessions...")
    token = get_token()
    if token:
        data = get_active_sessions(token)
        if data:
            df = parse_sessions(data)
            df = add_features(df)
            with open('baseline_model.pkl', 'rb') as file:
                model = pickle.load(file)
            anomalies = detect_anomalies(df, model)
            if anomalies.empty:
                print("No anomalies detected.")
            else:
                for index, row in anomalies.iterrows():
                    message = (f"Anomaly detected:\n" f"IP Address: {row['ipAddress']}\n"
                                f"Identity: {row['name']}\n" f"Country: {row['country_name']}\n"
                                f"Hour: {row['hour']}\n" f"CreatedAt: {row['createdAt']}\n"
                                f"UpdatedAt: {row['updatedAt']}\n" f"IdentityId: {row['identityId']}\n"
                                f"CachedLastActivityAt: {row['cachedLastActivityAt']}\n")
                    disable_identity(row['identityId'], 3, token)
                    send_slack_message(message, slack_webhook_url)
            print("Anomalies detected:", anomalies)
```

21. Job to be executed with all processes

Here we have the job that will be executed where as a flow of processes we have to retrieve the active sessions from the API with the dynamic token, preprocess these data, add manipulations to make as we need them to be structured and displayed and then load and read the binary file of the baseline model. This will be provided as a parameter for the detection of anomalies function, which does a prediction on the anomalies based on the two features that we extracted and marks with -1 the anomaly data. We iterate through these anomalies if any is found and then we send messages in a slack channel using a webhook and API for this

post request. This way whoever is part of that channel is notified and alerted for this suspicious session that is created.

```
def detect_anomalies(df, model):
    features = df[['hour', 'country']]
    df['anomaly'] = model.predict(features)
    return df[df['anomaly'] == -1]

def send_slack_message(message, webhook_url):
    headers = {'Content-Type': 'application/json'}
    data = {'text': message}
    response = requests.post(webhook_url, headers=headers, json=data)
    if response.status_code != 200:
        raise ValueError(f"Request to Slack returned an error {response.status_code}, the response is: {response.text}")
```

22. Anomaly Detection Function and Slack Alerts API

2.10 Response and Mitigation

For reducing the threat that might be from the anomalies that we pointed out, we bring a function built up over another API that will automate the process of disabling the identities for a short period of time. We judged this optimal time to be 30 minutes in order for the IT team to identify if the alarm is really something to worry about, having all the information about the identity and session in real time. This is the endpoint where we have the id of the identity with anomaly behavior and we can use it as a parameter together with the minutes it needs to be disabled.

```
def disable_identity(identity_id, duration_minutes, token):
    url = f"https://ec2-180-25-159-180.compute-1.amazonaws.com:8441/edge/management/v1/identities/{identity_id}/disable"
    headers = {
        "Content-Type": "application/json",
        "zt-session": token
    }
    data = {'durationMinutes': duration_minutes}
    response = requests.post(url, headers=headers, json=data, verify=False)
    if response.status_code == 200:
        print(f"Identity {identity_id} disabled for {duration_minutes} minutes.")
    else:
        print(f"Failed to disable identity {identity_id}. Response: {response.status_code}, {response.text}")
```

23. Disabling Identity Temporarily

2.11 Running and Testing

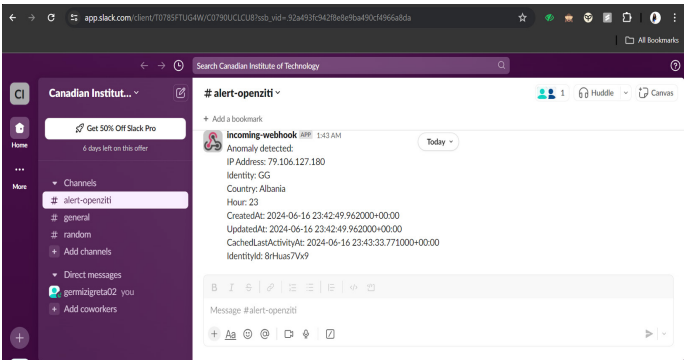
For testing purposes and demonstration we took some random data assuming employees will have their session create hour at least at 8 AM and at most 6 PM (18). As well as, we took some IP addresses where the country is different from Albania in order for us to understand that when we enter at 8 PM (20) and have an IP address originating from Albania we are considered as an anomaly compared to the normal data on the baseline model that is created with the random data.

```
Run: anomaly_detect x
2 2024-06-16 22:18:24.611000+00:00 ... 1
3 2024-06-16 22:46:15.575000+00:00 ... 1
4 2024-06-16 22:50:16.783000+00:00 ... 1
5 2024-06-16 23:32:10.476000+00:00 ... 0

[6 rows x 9 columns]
Identity i6RXFejQx9 disabled for 3 minutes.
Identity Zo6ZVhzWfa disabled for 3 minutes.
Identity 8rHuas7Vx9 disabled for 3 minutes.
Anomalies detected: createdAt ... anomaly
2 2024-06-16 22:18:24.611000+00:00 ... -1
3 2024-06-16 22:46:15.575000+00:00 ... -1
4 2024-06-16 22:50:16.783000+00:00 ... -1
```

24. Anomaly Detection Running and Results

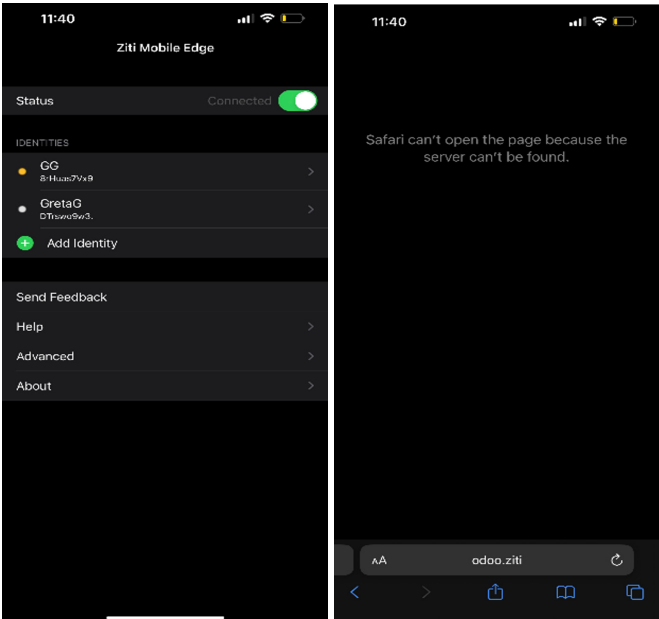
Here we can see the simulation with three identities with IP ranges originating from Albania that have created a session at 10 PM (22) and are disabled for a range of minutes that is predefined in this testing case for 3 minutes in order to try accessing again after this timestamp. The alert also is in real time where some notification comes when this session created is considered as an anomaly. The identity GG that was depicted as an



25. Slack Channel Alert Notification

anomaly is disabled and cannot access any service related even the policies defined are configured in that way to access the service. Here comes the role of the IT that can take measures towards this identity by removing access policies, or just accepting this as normal behavior and adding to the baseline model by updating the training data and retraining once again to account for these new normal behaviors. This could be done by a cron job scheduled for retraining the model with the appended data.

Here as it is shown in the identity the yellow dot means that is disabled temporarily and this GG identity cannot access the Odoo Service.



26. Disabled Identity No Access to Service

RESULTS

Implying all the security measures that are applicable to Zero Trust Network Architecture, this implementation roadmap using only open-source tools proved the effectiveness as well as the practicality for any kind of organization to enhance the security posture with this robust framework. By using open-source and vendor-neutral tools, we avoided vendor lock-in, allowing flexibility in tool selection and integration with other technologies. The modular approach used, demonstrated the flexibility for adoption in the scale the organization wants to, facilitating the process with automated deployment. Throughout this implementation, there are observed several advantages that highlight the importance of embracing ZTNA principles in today's cyberthreat landscape. With the implementation of a micro-segmented network architecture and the application of granular access policies we revealed the importance of limiting lateral movement through the network in order for the identity user not to access any other part that is not supposed to. The proposed solution to integrate User Behavior Analysis by using machine learning algorithms over Zero Trust Architecture proved to be a necessity in order to monitor in real-time any anomaly detected in the normal baseline profile that the everyday user has for any feature we define as crucial. By configuring alerts for any detected anomaly in a channel of communication, that could be easily modified in any other platform the specific organization uses for daily communications, we managed to reduce the operational burden on IT and security teams while deactivating temporarily the identity accesses until a second confirmation. This way we achieved response mechanisms and simplified management.

In summary, by embracing the Zero Trust Network Architecture with open-source tools, organizations can achieve a scalable, cost-effective, and robust security framework. This implementation demonstrated that comprehensive security measures were not only easily applicable but also essential for defending against modern cyber threats, ensuring that even smaller organizations could enhance their security posture without significant financial constraints. The practical outcomes and demonstrated benefits underscored the critical need for adopting ZTNA in today's dynamic network environments.

DISCUSSIONS

While these results affirm the value of ZTNA, certain limitations remain. Specifically, the scalability of machine learning models in high-traffic, real-time environments could present challenges for organizations with larger or more complex network infrastructures. As the volume of data increases, so do the computational demands, potentially affecting real-time detection capabilities. Additionally, implementing ZTNA across complex network architectures may require further adjustments or optimizations to ensure consistent and efficient performance across diverse use cases.

Future research could address these challenges by exploring more advanced or specialized machine learning models capable of handling the scale and diversity of large enterprise environments. Investigating alternative anomaly detection techniques such as ensemble learning or hybrid approaches may also enhance detection accuracy and reduce false positives. Continuous policy refinement, use case testing, and the addition of security layers in authentication are critical for adjusting to changing threats. Establishing long-term monitoring and assessment procedures will guarantee that security measures remain effective and resilient. Comparative studies between ZTNA and other cybersecurity frameworks could provide additional insights into ZTNA's unique strengths and potential limitations in various network settings.

CONCLUSIONS

This study demonstrates the practicality and effectiveness of implementing a Zero Trust Network Architecture (ZTNA) framework using open-source, vendor-neutral tools, proving that robust cybersecurity measures are accessible to organizations of any size. Our approach showcases how ZTNA, when integrated with machine learning-driven User Behavior Analysis (UBA), enhances real-time threat detection and response capabilities. By incorporating a micro-segmented network architecture and granular access policies, this implementation effectively minimizes lateral movement within the network, reducing the risk of data breaches and unauthorized access. This research, therefore, highlights the potential of open-source ZTNA as a flexible, scalable, and cost-effective cybersecurity solution that supports organizational resilience in an evolving threat landscape.

Key outcomes from this implementation include substantial reductions in the attack surface, real-time monitoring of user activity, and automated alerts and response mechanisms for anomalies, which collectively ease operational demands on security teams. The modularity of this open-source ZTNA approach offers scalability, enabling organizations to tailor the framework to their specific requirements and resources.

By addressing insider threats—a growing concern that accounts for a significant portion of data breaches—this study positions ZTNA as a valuable approach for protecting sensitive data without the need for proprietary solutions, which often impose significant financial and logistical constraints.

Despite these positive outcomes, our research identifies some challenges that warrant further exploration. The scalability of real-time anomaly detection in high-traffic environments, for instance, presents limitations as the volume of data increases, affecting processing capabilities and potentially introducing latency. Future work could focus on optimizing these models to handle large-scale data more effectively or exploring hybrid detection methods, such as ensemble learning, to enhance detection accuracy while reducing false positives.

Additionally, continuous policy refinement remains essential to ensure that ZTNA frameworks adapt to evolving threat landscapes. Future research should consider long-term monitoring strategies, automated policy adjustments, and advanced authentication layers to enhance resilience against sophisticated attacks. Comparative studies with alternative cybersecurity frameworks would also provide valuable insights into the unique benefits and limitations of ZTNA, further informing best practices for diverse network environments.

In conclusion, this study underscores the value of open-source ZTNA as a scalable, adaptable, and affordable solution for modern cybersecurity challenges. By blending Zero Trust principles with machine learning-driven behavioral analytics, this research contributes to the broader discourse on cybersecurity frameworks and highlights an accessible pathway for organizations to achieve high levels of security without excessive costs. Our findings demonstrate that robust, adaptable security measures can be deployed universally, ensuring that organizations remain resilient against today's complex and evolving cyber threats.

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