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INTELLIGENT METHODS FOR ANALYSING BANKING PROCESSES

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ABSTRACT

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INTRODUCTION

The concept of “Artificial Intelligence”(AI) arises in the middle of the last century. Founder of the theory of AI is mathematician Alan Turing. During the 1950, he created the well-known test- Imitation game. By means of this test it is identify the intelligence of the machine. Until the 1955, there was no single term to cover neural networks and natural language. For the creator of the term of the AI it is considered John Makkarty from college of Dortmund, USA. At the conference held in 1956 under his leadership, AI its development and potential areas for research were discussed.

In subsequent years, the trend in AI development has not been consistently upward. In 70 years stagnation occurs in his development. It is a consequence of unjustified expectations and interrupted research funding. Then the AI theme returns in the form of “expert system”. These programs answered questions and solve problems in different fields. In the late 80’s and early 90’s it experienced a new stagnation. Research funding has almost sopped again. In the following years, a number of events occur that show the importance of AI and change the trend in its development.

In banking, artificial intelligence plays an important role. It is used for customer service, fraud protection and last but not least for data analysis, investment decisions and risk management. In this way, managing credit institutions try to find the best solution and extract higher profits.

More and more banks are using chatbots and digital bankers. The clients of the bank using their services receive the needed analysis and decision for investment.

Data sharing creates prerequisites for the development of business models, based and analyzing datasets and thereby stimulating the development of the digital economy.

In practice, various terms are used for Artificial Intelligence. Among them are ‘smart’, ‘intelligent’, ‘predictive’ and ‘cognitive’. AI software has a wide variety of applications in a number of fields.

Nowadays, it is also used to analyze data and make decisions as a result of processing large databases that are complex and difficult for humans. Thus, it is part of management process, for example in the field of finance. Through artificial intelligence, data is processed, processes are analyzed, risk is assessed and intelligent solutions are proposed.

The results of the McKinsey Institute's latest global study on AI show that its use continues to grow and that the benefits remain significant, especially in the years of the COVID-19 pandemic. As business use of AI becomes more widespread, the tools and best practices for getting the most out of it also become more sophisticated.

McKinsey Institute researchers looked at the practices of companies seeing the greatest increase in profits from the use of artificial intelligence and found that they not only followed more of both basic and advance practices, including machine learning operations, which are in the foundation of success, but also spend more effectively on AI and cloud technologies. In addition, they are more likely than other organizations to engage in a range of activities to mitigate AI risk- an area that continues to be a shortcoming for many companies' AI efforts. Survey respondents claim that 27% of their earnings before interest and taxes(EBIT) is attributable to AI, increasing by 22% in one year.

Along with the development and increasingly widespread use of artificial intelligence, there is also talk about the potential risk of its use. At the European level, the European Commission has published a number of documents and strategies regarding AI.

The commission also published an official definition of AI in 2018. " Artificial Intelligence" refers to systems that display intelligent behavior by analyzing their environment and with a certain degree of autonomy, take actions to achieve specific goals. In practice , we use AI on a daily basis, for example to block someone from accessing our email box or to chat with digital assistants.

Increased computing power, availability of data, and advances in algorithms have made AI one of the most important technologies of the 21st century.

In 2020 EC published the so-called "White Paper on artificial intelligence – a European approach to excellence and trust". Recognizing the great importance of artificial intelligence for the development of various areas of our lives, the Commission expresses concern regarding some potential risks such as non-transparent decision making, based on gender or other types of discrimination, interference with our private lives.

In their activities, banks use internal model to calculate the minimum capital requirements for credit risk, for market risk and for operational risk. These are statistical models which bank can use to determine how much capital they need.

The more risks a bank takes the more capital it has to maintain. EU banks rules require them to maintain sufficient capital to cover unexpected losses caused by the risks in their portfolios. This is the capital adequacy requirement. When measuring these risks to determine whether it meets the capital adequacy requirement, the bank may use either:

- Standardized approach defined be regulatory authorities or
- Own internal models that must meet specific conditions – also determined by regulatory authorities.

The use of such models is subject to approval by the central bank or the ECB. After an in-depth assessment of the internal models of the credit institution, models for assessing risks and merging minimum capital requirements can be developed.

Typical activities with current monitoring of the models include:

- An assessment of the extent to which the institution complies with the supervisory measures laid down by ECB decision as well as whether it complies with the implementation plans and any other supervision and measures imposed on it relating to the model;

- Analysis of the validation results of the bank's internal credit risk and operational risk models, as well as the results of back tests and dynamic series for internal models for market risk;

- Assessment of the result of the EBA's annual benchmarking of internal models for market risk and credit risk;

- Evaluation of non-material changes and excavation of the scope of models.

In addition to internal models for regulatory purposes, bank also use other sophisticated methods to evaluate their activities, to assess their effectiveness and customer satisfaction.

Financial statement of credit institutions are also subject to analysis by external users. Their purpose may be related to future interaction, for the purpose of investment, or for the purpose of proving some thesis or evaluating a developed model or analysis.

In the current dissertation, financial reports and data of credit institutions from the European Union are analyzed by using the well-known of specialist the InterCriteria Analysis.

Current dissertation aims to develop, with the support of modern tools and intelligent systems, highly efficient intelligent methods to analyzed the processes in banking. To achieve this goal, the following tasks are formulated:

1. To carry out a critical analysis of the possibility of applying multi-criteria decision-making approach – Inter Criteria Analysis in the analysis of the processes in the banking;

2. To apply intelligent techniques for analyzing the mechanism of work of financial institution in the EU, according to which the banking system functions;

3. To conduct an analysis of the activities of the participants in the financial system in EU member countries;

4. To conduct an analysis of the financial indicators of member countries of EU;

5. To carry out a comparative analysis of the financial indicators of banks in EU member states;

6. To propose intelligent techniques for the analysis of knowledge bases and their application in practice.

The achieved results of the analogue of the conducted research are presented in a refereed scientific publication from the series Lecture Notes in Networks and Systems at Springer. International Publishing and in the proceedings of several international conferences, such as 10-th International Conference on Intelligent System IS 20, International Symposium on Bioinformatics and Biomedicine, BioInfoMed 20, International Conference Automatics and Informatics-ICAI21, 11-th International Conference on Intelligent System-IS22 and International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets-IWIFSGN22.

The dissertation is structured in an introduction, three chapters and a conclusion, and is accompanied by a declaration of originality, of the obtained results and a bibliography.

Original results related to research in the field of intelligent system have been achieved, using analytical and experimental models.

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CHAPTER 1

AN OVERVIEW OF THE INTELLIGENT METHODS FOR AN ANALYSIS OF COMPLEX PROCESSES

Artificial intelligence emerged as a scientific field in the first decade after the World War II. The term “Artificial Intelligence” itself appeared later. At the historic summer seminar in Dortmounth (USA) in 1956, organized by John McCarthy(author of the LISP programming language), the term was adopted for the first. Among those present at the seminar were nine other presenters specialists in the field, including Marvin Minsky(who made huge contributions to neural networks, frame structures and knowledge representation theory), Claude Shannon (author of information theory), Allen Newell and Herbert Simon (creators of the first computer program capable of proving theorems, called Logic –Theoretic), Arthur Samuel (wrote the first self-learning machine programs).

1.1. Computational intelligence

In the last two decades there appeared gradually a new scientific field, which was termed “Computational intelligence”, one of the most popular definitions of computational intelligence in the respective academia is of the following type:

“Computational intelligence is a methodology, including calculations, showing possibilities for training and/or for coping with a new situation, so that the system is comprehended as having one or more attributes of judgements, such as summary, opening, association and abstraction“.

1.2. Basic approaches in computational intelligence

The scientific approaches, using in computational intelligence are equally accessible for AI, but the directions and goals in their development are different. Most of them have their roots in classical AI, but someone are independent scientific disciplines.

The basic approaches in computational intelligence are as follow:

1. Fuzzy systems;
2. Artificial neural networks;
3. Support Vector Machines;
4. The evolutionary calculus;
5. Swarm Intelligence;
6. Intelligent agents

1.3. Intelligent systems

"**Intelligent systems**" is a term, having a wide scope and not accepted in a straightforward fashion. The magazine "Intelligent Systems" of the biggest professional organisation globally - Institute of Electrical and Electronics Engineers - IEEE is focused mainly on informatics, while in the numerous international scientific forums devoted to the intelligent systems, there is much wider understanding in the direction of interdisciplinary and multidisciplinary approach. There is special emphasis on the term "intelligent", whose content corresponds to a great extent, in terms of sense and scope, to the terms and techniques, considered above.

1.4. Intuitionistic Fuzzy Sets

Lotfi Aliasker Zadeh defined the theory of the Fuzzy Sets (FS) in 1965 as a mathematical apparatus for an adequate description of the inaccuracy and uncertainty in nature. A proof of the increasing interest in these were the developments, defined subsequently: L-FS (L-Fuzzy Sets) of Goguen, FS with interval values (Interval Valued

Fuzzy Sets) of Gorzalczany, rough sets of Pawlak and intuitionistic fuzzy sets (IBS) of Kr. Atanassov.

1.4.1. Definition of IFS

A represents an intuitionistic fuzzy set (IFS), the description of which has the following form:

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in E \ \},$$

where E is a fixed set, function $\mu_A : E \to [0,1]$ sets the corresponding degree belonging to the function $\nu_A : E \to [0,1]$ - the corresponding of membership of the element $x \in E$ multitude $A \subseteq E$ and for every $x \in E$ it is fulfilled:

$$0 \le \mu_A(x) + \nu_A(x) \le 1.$$

Function π_A is described by a mathematical expression:

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x),$$

Which sets the degree of uncertainty of the element's belonging $x \in E$ to a multitude A. Obviously FS is a private case of IFS when $\pi_A(x) = 0$ for every $x \in E$.

1.4.2. Operations and relations for IFS

The operations and relations defined for IS are a generalization of the operations and relation for fuzzy sets.

1.4.4. Operators over IFS

In the theory of IFS, the operators "necessary" (□) and "possible" (□), are defined, which convert IFS into FS.

1.5. Indexed matrices

In practice, so-called multi-criteria decision-making tasks are rise. Heterogeneous and diverse can be both the criteria and the available data obtained by measuring or

foaming the objects against the criteria. Some times measuring or evaluating some of the criteria can be slow, expensive , resource intensive etc. In such cases, for decision maker it would be of significant benefit to be able to ignore all or part of these unfavorable criteria in future decision-making without significant loss of accuracy.

1.6. Method of InterCriteria Analysis

The method of InterCriteria Analysis was introduced in. It is based on two mathematical formalisms – the apparatus of the index matrices for the processing of data batches with various sizes, and intuitionistic fuzzy sets as a mathematical instrument for the treatment of uncertainty.

Let M be an index matrix, built up in the following way:

$$M = \begin{array}{c|ccccccc} & O_1 & \dots & O_k & \dots & O_l & \dots & O_n \\ \hline C_1 & a_{C_1,O_1} & \dots & a_{C_1,O_k} & \dots & a_{C_1,O_l} & \dots & a_{C_1,O_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ C_i & a_{C_i,O_1} & \dots & a_{C_i,O_k} & \dots & a_{C_i,O_l} & \dots & a_{C_i,O_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ C_j & a_{C_j,O_1} & \dots & a_{Cj,O_k} & \dots & a_{C_j,O_l} & \dots & a_{C_j,O_n} \\ \vdots & \vdots & & \vdots & & \vdots & & \vdots \\ C_m & a_{C_m,O_1} & \dots & a_{Cm,O_k} & \dots & a_{Cm,O_l} & \dots & a_{Cm,O_n} \end{array} \quad (12)$$

where for each p, q ($1 \leq p \leq m$, $1 \leq q \leq n$): C_p is criterion; O_q is object; $a_{Cp,Oq}$ is the evaluation of the q-th object against the p-th criterion.

In detail, according to the table presented below the relations between the criteria are termed “strong positive consonance”, “positive consonance”, “weak positive consonance”, “weak dissonance”, “dissonance”, “strong dissonance”, “weak negative consonance”, “negative consonance” or “strongly negative consonance”.

Table 1.1. Relation between the criteria

Degree of relation	***Type of consonance***
[0; 0,05]	Strongly negative consonance (SNC)
[0,05; 0,15)	Negative consonance (NC)
[0,15; 0,25)	Weak negative consonance (WNC)
[0,25; 0,33)	Weak dissonance (WD)
[0,33; 0,43)	Dissonance (D)
[0,43; 0,57)	Strong dissonance (SD)
[0,57; 0,67)	Dissonance (D)
[0,67; 0,75)	Weak dissonance (WD)
[0,75; 0,85)	Weak positive consonance (WPC)
[0,85; 0,95)	Positive consonance (PC)
[0,95; 1]	Strongly positive consonance (SPC)

CHAPTER 2

ANALISING OF PROCESSES IN BANKING

The search and development of new, intelligent methods for analyzing banking processes is an actual scientific problem. Its relevance is determined by the changed economic environment, by the need for rapid development and digitization of banking services and above all, by accurate analyzes of the processes in credit institutions, the risk to which they are exposed and the interpretation of data and evaluation of their management.

2.1. Emergence of banks

Banks originated in ancient times, in the first city-state. One of the first banking system was in Babylon, which arose about 2000 years ago. Ancient Babylon temples accumulated money from donations and began to provide loans to entrepreneurs.

The historical development of banks goes though different stages depending on the development of countries and their economies. Banks have always been helpful to the population and provided the requested services. By attracting a resource, they make it available to those seeking funding.

2.2. History of banking in Bulgaria

The establishment of banks and the development of banking in Bulgaria is conditioned by its historical development. Before the Liberation of Bulgaria, there were no Bulgarian banks. Before that, our country was part of Turkish Empire for a long time. Established in 1857 Ottoman Bank had offices in Bulgaria, but cannot be considered as the first Bulgarian bank.

In 1859, an attempt was made in Bulgaria to create banks, in the form of mutual funds. After the Liberation, they functioned as agrarian funds, supporting rural fermers

and thus marked the beginning of banking in Bulgaria. The first Bulgarian bank was the Bulgarian National Bank (BNB) established in 1879. Initially, it did not have the right to mint coins, print and put money into circulation. Later, with a change in its charter in 1885, it already has this right and issues the first Bulgarian banknotes. BNB plays an important role in the economic life of the country. It has been the central bank of Bulgaria since 2007 after the acceptance of Bulgaria as a part of the European Union BNB becomes part of the system of European Central Banks (ECB).

2.3. New technologies and the development of banking in the world

On Fig 2.1 the most important points in the field of finance are presented.

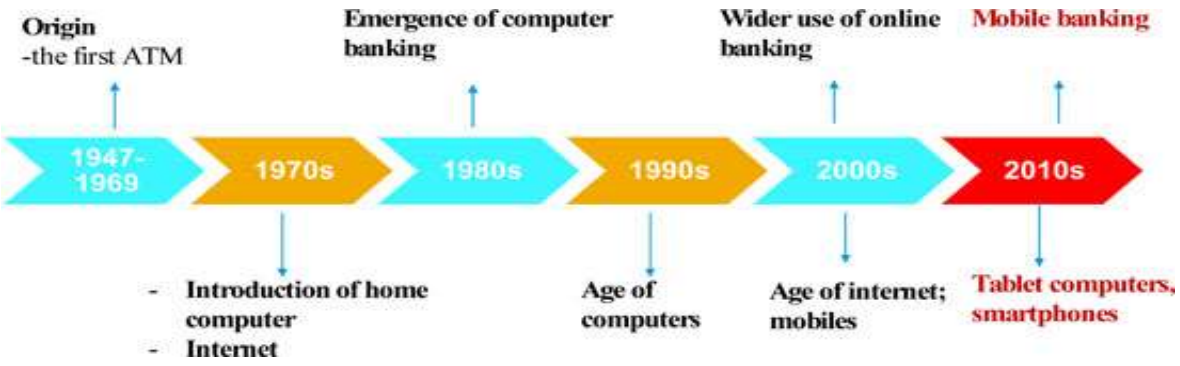

Fig 2.1. The history of digital technology

Electronic banking began with the advent of ATMs and cards issued in the 1960s. Through them users can receive cash, make deposits, pay utility bills and ets.

The most important event in the development of bank in the 20th century is the appearance of on-line banking which in its earliest form is from the 80s. The biggest boost in his early days is the appearance on the internet in the mid-90s.

2.4. Analysis of business financing processes in Europe

Each country's economy is financed differently from different sources. Banks are the main source of financing for companies.

2.5. Analysis of bank regulation in Europe

Bank and more specifically their activity is one of the most regulated in the world. In Europe, the countries that are part of the European Union, the activity of their banks is controlled by the supervisory institution of the given country and by the European Central Bank(ECB). This represents the so-called Single Supervisory Mechanism. The ECB is an independent institution of the European Council. Its role consists in the following establishment of a unified ongoing supervision of credit institution, monitoring and ensure the application and compliance, with uniform harmonized rules and taking when necessary corrective action. To achieve these goals, the ECB works in close cooperation with national supervisory authorities.

2.6. Requirements for accountability of banks in Europe

As of 28.06.2021, the requirements for reporting by credit institutions are regulated in the Implementation Regulation 2021/451, which replaces the Implementation Regulation 680/2014. The Implementation Regulation 2021/451 establishes uniform reporting formats and templates guidelines and methodology for the use of these samples, frequency and dates of reporting, definitions and information technologies for reporting.

The periodicity and reports is also indicated in the regulations. Based on the reports received, on a quarterly basis the ECB publishes aggregated information on the monitored credit institutions. This represents the Supervisory Banking Statistics, Fig. 2.3.

Fig. 2.3. Supervisory Banking Statistic

The information in this report is presented entirely in tabular form. It is divided into six main areas – General Statistics, Balance Sheet Composition and Profitability, Capital Adequacy and Leverage, Asset Quality, Funding and Liquidity.

The total number of tables in the various reports varies from 59 to 62. The information in tables is generally divided by reporting period, by country and by classification. It is at the highest consolidated level. Some country for reasons of confidentiality do not give permissions for certain data to be published. Bulgaria, for example, participates with one significant bank whose data is not published in the Supervisory Banking Statistic.

Because of this reason in our research we chose and analyzed the information about banks in eight European country for which complete information is available. These are Germany, Spain, France, Italy, Luxembourg, Netherlands, Austria and Portugal. From

the tables in Supervisory Banking Statistic we chose to analyze data of Profit and losses by country, Key performance indicators by country and NPL's and advances by country.

Profit and loss figures by country for Q4 2020 is 13 and for Q4 2021 is 15. The differences are due to a changed, to more detailed reporting of gains and losses from financial assets and liabilities.

2.7. Analysis of competitiveness of the world's economies

Other data that we analyzed are the data published in the year's competitiveness reports. The Global Competitiveness report of the World Economic Forum, Switzerland. These were the last years in which such a report has been published. For 2020 there is report, but it is not in the same format.

The Global Competitiveness report measures the competitiveness of countries and their economies. For the purpose of analysis, we settled on this reports. We used the data for 2018 and 2019.

Fig. 2.4. The Global Competitiveness report

In 2018, the World Economic Forum presents The Global Competitiveness index in its report. In the wake of globalization and the fourth industrial revolution, the forum's researches decided that a new economic compass was needed. Based on their 40 years of experience in analyzing competitiveness and accumulated data, they create this index, which they publish in The Global Competitiveness report. The information in the report is organized and divided into four main areas in which 12 Pillars are distributed and in each of them there are several indicators. These are Enabling Environment with Pillars – 1. Institutions; 2. Infrastructure; 3. Internet, computers and communications; 4. Macroeconomic stability. Human capital with Pillars – 5. Health and 6. Skills. Market with Pillars – 7. Product market, 8. Labor and 9. Financial system. 10 Market size. Innovative ecosystem with Pillars 11. Business dynamic and 12. Innovative ability.

CHAPTER 3

EXPERIMENTAL RESULTS OF THE APPLICATION OF INTELLIGENT METHODS FOR ANALYSING OF BANKING PROCESSES

This chapter of the dissertation presents the results of the analysis. The method-InterCriteria Analysis was used , which was originally developed to reflect the situations where some of the criteria have a higher cost than others, such as their evaluations are more difficult to obtain, more expensive and/or take longer.

3.1. Analysis of the financial system of EU member states

In publication[1] parameters of the parties are analyzed in detail using the multi-criteria making methods – InterCriteria Analysis. Data from 2019 Annual Report on the Competitiveness of Countries were used as the source data.

The analyzed data from the report measuring competitiveness are from Pillar 9 – Financial system with indicators – *1. Domestic credits to private sector as a % GDP; 2-Financing of small and medium –sized business; 3. Venture capital availability; 4. Market capitalization as a % of GDP; 5. Insurance premiums as volume of GDP; 6. Stability of the banks; 7. Non-performing loans as % of total loans; 8. Credit GAP in %; 9. Regulatory requirements for capital ratio as % of total risk –weighted assets.*

The aim is to show the relationship between these economic indicators by applying a multi-criteria methods for taking decisions – InterCriteria Analysis. Those selected by the authors of the report are the result of data processing of various institutions and a digital evaluation of a conducted survey.

A detailed description of the indicators and Pillar 9 on the report is provided in Chapter 2 of this dissertation.

Economy Profiles

Bulgaria

51st/140

Index Component	Value	Score *	Rank/140	Best Performer
Pillar 7: Product market 0-100 (best)	-	**56.7** ↑	**62**	**Singapore**
7.01 Distortive effect of taxes and subsidies on competition 1-7 (best)	3.3	38.1 ↑	107	Singapore
7.02 Extent of market dominance 1-7 (best)	3.7	45.0 ↓	71	Switzerland
7.03 Competition in services 1-7 (best)	5.2	69.5 ↑	50	Hong Kong SAR
7.04 Prevalence of non-tariff barriers 1-7 (best)	4.2	53.6 ↓	89	Singapore
7.05 Trade tariffs % duty	1.13	92.4 ↓	24	Hong Kong SAR
7.06 Complexity of tariffs 1-7 (best)	3.0	33.7 ↓	112	Hong Kong SAR
7.07 Efficiency of the clearance process 1-5 (best)	2.9	48.4 ↑	43	Germany
7.08 Services trade openness 0-100 (worst)	15.5	84.5 =	17	Ecuador
Pillar 8: Labour market 0-100 (best)	-	**62.0** ↑	**50**	**United States**
8.01 Redundancy costs weeks of salary	8.6	90.4 =	18	Multiple (8)
8.02 Hiring and firing practices 1-7 (best)	3.8	46.9 ↑	69	Hong Kong SAR
8.03 Cooperation in Labour-employer relations 1-7 (best)	3.8	46.3 ↓	118	Switzerland
8.04 Flexibility of wage determination 1-7 (best)	5.2	70.2 ↑	44	Hong Kong SAR
8.05 Active Labour policies 1-7 (best)	3.4	40.6 ↑	65	Switzerland
8.06 Workers' rights 0-100 (best)	79.4	79.4 ↑	39	Multiple (4)
8.07 Ease of hiring foreign labour 1-7 (best)	3.8	46.4 ↓	100	Albania
8.08 Internal Labour mobility 1-7 (best)	4.7	61.3 ↑	50	Guinea
8.09 Reliance on professional management 1-7 (best)	3.5	42.1 ↓	112	Finland
8.10 Pay and productivity 1-7 (best)	3.7	45.6 ↑	81	United States
8.11 Female participation in Labour force ratio	0.88	84.5 ↓	36	Multiple (4)
8.12 Labour tax rate %	20.2	83.1 =	93	Multiple (26)
Pillar 9: Financial system 0-100 (best)	-	**58.2** ↑	**71**	**United States**
9.01 Domestic credit to private sector % GDP	55.9	58.9 ↓	62	Multiple (29)
9.02 Financing of SMEs 1-7 (best)	3.7	45.3 ↑	77	United States
9.03 Venture capital availability 1-7 (best)	3.2	37.1 ↑	50	United States
9.04 Market capitalization % GDP	14.4	14.4 =	86	Multiple (12)
9.05 Insurance premium % GDP	2.1	34.4 =	57	Multiple (16)
9.06 Soundness of banks 1-7 (best)	4.5	59.1 ↑	88	Finland
9.07 Non-performing loans % loan portfolio value	13.2	74.4 ↑	114	Multiple (2)
9.08 Credit gap percentage points	-17.0	100.0 =	9	Multiple (97)
9.09 Banks' regulatory capital ratio ratio	20.4	100.0 =	22	Multiple (72)
Pillar 10: Market size 0-100 (best)	-	**54.6** ↑	**64**	**China**

Fig. 3.1. Data for financial system in EU countries

The obtained results of the analysis are shown in Table 3.1 and Table 3.2.

μ	1	2	3	4	5	6	7	8	9
1	1.000	0.569	0.560	0.689	0.655	0.520	0.462	0.406	0.446
2	0.569	1.000	0.855	0.680	0.597	0.766	0.132	0.628	0.615
3	0.560	0.855	1.000	0.680	0.600	0.717	0.166	0.625	0.625
4	0.689	0.680	0.680	1.000	0.791	0.640	0.326	0.505	0.578
5	0.655	0.597	0.600	0.791	1.000	0.535	0.418	0.449	0.465
6	0.520	0.766	0.717	0.640	0.535	1.000	0.169	0.680	0.597
7	0.462	0.132	0.166	0.326	0.418	0.169	1.000	0.298	0.280
8	0.406	0.628	0.625	0.505	0.449	0.680	0.298	1.000	0.618
9	0.446	0.615	0.625	0.578	0.465	0.597	0.280	0.618	1.000

Table 3.1. Values of μ

ν	1	2	3	4	5	6	7	8	9
1	0.000	0.391	0.388	0.308	0.338	0.449	0.532	0.591	0.548
2	0.391	0.000	0.065	0.277	0.357	0.169	0.822	0.329	0.338
3	0.388	0.065	0.000	0.265	0.342	0.200	0.782	0.320	0.317
4	0.308	0.277	0.265	0.000	0.206	0.326	0.665	0.489	0.412
5	0.338	0.357	0.342	0.206	0.000	0.428	0.569	0.542	0.523
6	0.449	0.169	0.200	0.326	0.428	0.000	0.794	0.286	0.372
7	0.532	0.822	0.782	0.665	0.569	0.794	0.000	0.692	0.708
8	0.591	0.329	0.320	0.489	0.542	0.286	0.692	0.000	0.372
9	0.548	0.338	0.317	0.412	0.523	0.372	0.708	0.372	0.000

Table 3.2.Values of ν

The results of the conducted inter-criteria analysis show the following: Indicators 1 ("Local credits as % of GDP (Gross Domestic Product)") and 6 ("Stability of banks") are in strong dissonance; Indicators 1 ("Local loans as % of GDP (Gross Domestic Product)") and 7 ("Non-performing loans as % of total loans") are in strong dissonance; Indicators 2

("Financing of small and medium-sized businesses") and 3 ("Capital requirement for start-up businesses") are in positive consonance; Indicators 2 ("Financing of small and medium-sized businesses") and 7 ("Non-performing loans as % of total loans") are in negative consonance; Indicators 3 ("Startup capital requirement") and 4 ("Market capitalization as % of GDP") are in slight dissonance; Indicators 3 ("Capital requirement for start-up business") and 7 ("Non-performing loans as % of total loans") are in weak negative consonance; Indicators 4 ("Market capitalization as % of GDP") and 8 ("Credit gap in %") are in strong dissonance; Indicators 5 ("Insurance premiums as a volume of GDP") and 6 ("Stability of banks") are in strong dissonance; Indicators 6 ("Stability of banks") and 8 ("Credit gap in %") are in slight dissonance; Indicators 8 ("Credit Gap in %") and 9 ("Regulatory Capital Ratio Requirement as %") are in dissonance.

The analysis shows a dependency between criterion 2 ("Financing of small and medium-sized businesses") and criterion 3 ("Start-up capital requirement"). The main reason for this is that the data is taken after a study that shows the ability of small or start-up businesses to find money to finance their activities, their innovative ideas. There is a weak dissonance between criterion 6 ("Stability of banks") and criterion 8 ("Credit gap in %). The stability of the banks was assessed after a survey, i.e. it is a subjective assessment. The credit gap is considered an early indicator of an impending banking crisis. On the other hand, there is a weak correlation between criterion 6 ("Stability of the bank") and criterion 7 ("Non-performing loans as % of total loans"). This is due to the importance of these criteria. If a bank is in good shape, its level of non-performing loans is very low. The results obtained show that criterion 1 ("Domestic loans as % of GDP (Gross Domestic Product)"), criterion 7 ("Non-performing loans as % of total loans") and criterion 8 ("Credit gap in %") are in dissonance , both among themselves and with everyone else, i.e. they are independent criteria. Criterion 7 ("Non-performing loans as a % of total loans") has a numerical expression and is the result of the financial condition of the companies and their ability to service their obligations.

3.2. Analysis of the activities of the participants in the financial system of the EU member

In publication [3] of data from the 2019 Competitiveness Report of the World Economic Forum was expected to publish such a report on next year, but that didn't happen. Using the InterCriteria Analysis, the dependencies between the indicators analyzed by the 2019 report are again confirmed. The obtained results of the analysis are presented in the following tables.

The analyzed data from the report measuring the competitiveness of countries in the world for 2018 are from Pillar 9 – Financial system with indicators – *1. Domestic credits to private sector as a % GDP; 2- Financing of small and medium –sized business; 3. Venture capital availability; 4. Market capitalization as a % of GDP; 5. Insurance premiums as volume of GDP; 6. Stability of the banks; 7. Non-performing loans as % of total loans; 8. Credit GAP in %; 9. Regulatory requirements for capital ratio as % of total risk –weighted assets.*

μ	1	2	3	4	5	6	7	8	9
1	1	0,5328	0,5584	0,7407	0,6952	0,51	0,4501	0,3903	0,4103
2	0,5328	1	0,8376	0,6667	0,6182	0,755	0,1481	0,5983	0,5698
3	0,5584	0,8376	1	0,6809	0,6382	0,7151	0,1823	0,5926	0,6011
4	0,7407	0,6667	0,6809	1	0,7806	0,6125	0,3618	0,4758	0,4986
5	0,6952	0,6182	0,6382	0,7806	1	0,5556	0,4217	0,453	0,433
6	0,51	0,755	0,7151	0,6125	0,5556	1	0,1795	0,6895	0,5812
7	0,4501	0,1481	0,1823	0,3618	0,4217	0,1795	1	0,2934	0,3333
8	0,3903	0,5983	0,5926	0,4758	0,453	0,6895	0,2934	1	0,6125
9	0,4103	0,5698	0,6011	0,4986	0,433	0,5812	0,3333	0,6125	1

Table 3.3. Values of μ

The analysis of the data shows the existence of a dependency between criterion 1 ("Domestic lending to the private sector by banks as a % of GDP") and criterion 4 ("Market capitalization as a % of GDP"). Both indicators show the development of the economy and this is the main reason for their connection. This analysis also shows a dependency between Criterion 3 (Start-up Capital Requirement) and Criterion 2 (SME Financing). It shows the ability of small or start-up businesses to find capital to finance their business. Analyzing the rest of the results, it can be said that there is another dependence between criterion 6 ("Stability of banks") and criterion 8 ("Credit gap in %). In the analysis of the data, a weak dependence is noticed between criterion 6 ("Stability of the bank") and criterion 7 ("Non-performing loans as % of total loans"). Again, the explanation is that this is due to the importance of these criteria. If a bank is stable, its level of non-performing loans is very low or their amount is largely covered by assets.

v	1	2	3	4	5	6	7	8	9
1	0	0,4131	0,4046	0,2564	0,2906	0,4644	0,5385	0,604	0,5812
2	0,4131	0	0,0769	0,2821	0,3191	0,1709	0,792	0,3476	0,3732
3	0,4046	0,0769	0	0,2849	0,3162	0,2279	0,7806	0,3704	0,359
4	0,2564	0,2821	0,2849	0	0,208	0,3647	0,6296	0,5214	0,4957
5	0,2906	0,3191	0,3162	0,208	0	0,416	0,5584	0,5328	0,5499
6	0,4644	0,1709	0,2279	0,3647	0,416	0	0,7892	0,2849	0,3903
7	0,5385	0,792	0,7806	0,6296	0,5584	0,7892	0	0,7009	0,6524
8	0,604	0,3476	0,3704	0,5214	0,5328	0,2849	0,7009	0	0,3789
9	0,5812	0,3732	0,359	0,4957	0,5499	0,3903	0,6524	0,3789	0

Table 3.4. Values of v

The presented results also show a weak relationship between criterion 7 ("Non-performing loans as % of total credit") and criterion 8 ("Credit gap in %"). The main reason for this is that the credit gap is an early indicator for predicting a financial crisis. A high level of non-performing loans can be the cause of such a crisis. The conclusions drawn from the analysis of the data from the 2018 and 2019 competitiveness reports show that the strong and weak dependencies between the indicators are manifested in the same way. Through the method of InterCriteria Analysis, their influence is confirmed in an indisputable way, as a consequence of the economic importance of the indicators and the expected relationship between them.

3.3. Analysis of financial indicators of EU member state for 2020

In a publication [4], data from the ECB report – Supervisory Banking Statistics for 2020 were analyzed using the already known InterCriteria Analysis. By means of which an array of data is analyzed, interrelationships that may be invisible at first glance are shown, scientifically substantiated points are confirmed.

The analysis was made for eight selected EU member countries – Germany, Spain, France, Italy, Luxembourg, Netherlands, Austria and Portugal, for 2020 with the following indicators:

Profit and loss figures by country:

1. Net interest income;
2. Net fee and commission income;
3. Net trading income;
4. Exchange differences, net;
5. Net other operating income;
6. Operating income;
7. Administrative expenses and depreciation;
8. Net income before impairment, provision and taxes;

9. Impairment and provisions;

10. Other;

11. Profit and loss before tax;

12. Tax expenses or income;

13. Net profit/loss.

On Fig. 3.3. it is shown the data that using from the Supervisory Banking Statistics -4Q 2020 for Profit and loss figures by country.

Key risk indicators by country

14. RoA.

15. RoE.

16. COR.

17. CIR.

On Fig 3.4. there is data for key risk indicators that have been used from Supervisory Banking Statistics 4Q2020.

Non-performing loans by country

18. Loans and advances.

19. Non-performing loans and advances.

20. NPL's ration in %.

The economic nature of the indicators, data sources and reasons for selection are detailed in Chapter 2 of this dissertation.

T02.01.2 Profit and loss figures by country

(EUR millions; percentages)

Profit and loss [1] [2] (Q4 2020)	Total	Belgium	Bulgaria	Germany	Estonia	Ireland	Greece	Spain	France	Croatia [7]	Italy
Net interest income	**259,391.66**	6,602.34	C	31,677.44	572.04	5,549.98	5,524.05	58,965.95	69,909.25	-	28,082.09
Net fee and commission income	**140,314.47**	3,288.57	C	21,012.61	193.11	2,504.33	1,208.45	20,685.09	51,251.96	-	21,947.75
Net trading income	**22,140.27**	-126.95	C	3,019.84	6.35	241.61	59.32	4,587.49	12,292.42	-	938.07
Exchange differences, net	**-1,578.70**	350.28	C	106.50	28.62	48.39	42.06	-2,201.07	-711.84	-	545.22
Net other operating income [3]	**27,710.99**	233.86	C	3,857.33	88.58	1,034.75	2,553.57	3,833.25	7,534.51	-	5,484.07
Operating income [4]	**447,978.69**	10,348.09	C	59,673.72	888.69	9,379.07	9,387.45	85,870.72	140,276.31	-	56,997.20
Administrative expenses and depreciation	**-295,788.51**	-6,344.57	C	-45,666.86	-490.22	-6,501.54	-3,949.24	-45,199.62	-100,191.51	-	-41,654.56
Net income before impairment, provisions and taxes	**152,190.18**	4,003.52	C	14,006.86	398.47	2,877.53	5,438.21	40,671.09	40,084.80	-	15,342.65
Impairment and provisions [5]	**-118,222.53**	-1,648.59	C	-10,751.10	C	C	-6,086.51	-37,862.74	-22,621.72	-	-18,321.74
Other	**17,719.64**	318.59	C	48.39	C	C	-232.51	2,307.39	10,920.25	-	2,984.87
Profit and loss before tax [6]	**45,268.96**	2,673.52	C	3,333.46	340.14	-1,614.12	-1,245.18	-1,897.04	28,129.72	-	1,218.24
Tax expenses or income	**-21,754.74**	-529.89	C	-2,026.32	-40.16	148.01	-507.43	-7,119.13	-6,595.65	-	-744.09
Net profit/loss	**23,514.22**	**2,143.63**	C	**1,307.14**	**299.98**	**-1,466.10**	**-1,752.61**	**-9,016.17**	**21,534.07**	-	**474.15**
Net interest income/Operating income	***57.90%***	*63.80%*	C	*53.08%*	*64.37%*	*59.17%*	*58.85%*	*68.67%*	*49.84%*	-	*49.27%*
Net fee and commission income/Operating income	***31.32%***	*31.78%*	C	*35.21%*	*21.73%*	*26.70%*	*12.87%*	*24.09%*	*36.54%*	-	*38.51%*
Net trading income/Operating income	***4.94%***	*-1.23%*	C	*5.06%*	*0.71%*	*2.58%*	*0.63%*	*5.34%*	*8.76%*	-	*1.65%*

Profit and loss [1] [2] (Q4 2020)	Cyprus	Latvia	Lithuania	Luxembourg	Malta	Netherlands	Austria	Portugal	Slovenia	Slovakia [7]	Finland
Net interest income	742.16	C	339.07	1,159.84	301.76	29,559.47	10,161.27	3,137.96	C	-	6,159.69
Net fee and commission income	220.56	C	182.45	1,587.24	93.50	6,419.85	4,564.95	1,491.11	C	-	3,180.05
Net trading income	C	C	20.67	152.17	C	272.14	111.33	-74.72	C	-	516.22
Exchange differences, net	C	C	17.16	38.68	C	149.53	-111.05	184.51	C	-	C
Net other operating income [3]	64.63	C	17.85	276.19	3.42	1,548.15	716.06	-291.92	C	-	C
Operating income [4]	1,056.03	C	577.20	3,214.13	418.30	37,949.15	15,442.57	4,446.94	C	-	10,501.90
Administrative expenses and depreciation	-705.39	C	-257.88	-2,532.23	-313.62	-23,083.30	-9,389.93	-2,647.35	C	-	-5,945.55
Net income before impairment, provisions and taxes	350.64	C	319.32	681.90	104.68	14,865.85	6,052.64	1,799.59	C	-	4,556.35
Impairment and provisions [5]	C	C	-30.86	-190.11	C	-8,765.31	-2,879.99	-2,262.58	C	-	-1,273.97
Other	C	C	-0.24	8.09	C	280.14	172.75	167.75	C	-	C
Profit and loss before tax [6]	-95.24	C	288.27	499.87	-40.76	6,380.68	3,345.39	-324.62	C	-	C
Tax expenses or income	-17.71	C	-55.35	-114.80	-4.09	-2,291.61	-789.04	-292.60	C	-	C
Net profit/loss	**-112.95**	C	**232.93**	**385.07**	**-44.85**	**4,089.08**	**2,556.35**	**-617.22**	C	-	**2,806.80**
Net interest income/Operating income	*70.28%*	C	*58.74%*	*36.09%*	*72.14%*	*77.89%*	*65.80%*	*70.56%*	C	-	*58.65%*
Net fee and commission income/Operating income	*20.89%*	C	*31.61%*	*49.38%*	*22.35%*	*16.92%*	*29.56%*	*33.53%*	C	-	*30.28%*
Net trading income/Operating income	C	C	*3.58%*	*4.73%*	C	*0.72%*	*0.72%*	*-1.66%*	C	-	*4.92%*

Source: ECB.

Notes: Significant institutions at the highest level of consolidation for which common reporting (COREP) and financial reporting (FINREP) are available.

C: the value is suppressed for confidentiality reasons.

1) Profit and loss statement figures may be based on different financial years. To increase consistency, if the end of the financial year is not 31 December, a linear projection of the figures has been made for each reporting period.

2) Figures reported are year-to-date.

3)This includes, among other items, gains or losses resulting from the valuation of financial assets/liabilities at fair value, where those financial assets/liabilities are not reported as "held for trading".

4) Operating income before administrative expenses and depreciation are deducted.

5) Provisions include provisions for "commitments and guarantees given" and "other provisions".

6) Profit and loss before tax from continued operations (i.e. "net income before impairment, provisions and taxes" + "impairment and provisions" + "other") plus profit and loss before tax from discontinued operations.

7) There are no significant institutions at the highest level of consolidation in Croatia and Slovakia.

Fig. 3.3. Supervisory Banking Statistics for 4Q2020

T02.02.2 Key performance indicators by country

(percentages)

Country [1) 2)] (Q4 2020)	Return on equity (RoE)	Return on assets (RoA)	Cost-to-income ratio (CIR)	Cost of Risk (CoR) [4)]
Belgium	5.49%	0.37%	61.31%	0.61%
Bulgaria	C	C	C	C
Germany	0.57%	0.03%	76.53%	0.43%
Estonia	6.75%	0.82%	55.16%	0.30%
Ireland	-2.92%	-0.29%	69.32%	1.52%
Greece	-6.81%	-0.62%	42.07%	0.76%
Spain	-4.15%	-0.26%	52.64%	1.22%
France	4.23%	0.26%	71.42%	0.53%
Croatia [3)]	-	-	-	-
Italy	0.26%	0.02%	73.08%	0.73%
Cyprus	-3.26%	-0.27%	66.80%	2.54%
Latvia	C	C	C	C
Lithuania	10.60%	0.86%	44.68%	0.25%
Luxembourg	2.88%	0.21%	78.78%	0.16%
Malta	-2.52%	-0.20%	74.97%	1.26%
Netherlands	3.20%	0.18%	60.83%	0.49%
Austria	5.09%	0.43%	60.81%	0.74%
Portugal	-3.20%	-0.28%	59.53%	1.24%
Slovenia	C	C	C	C
Slovakia [3)]	-	-	-	-
Finland	5.84%	0.41%	56.61%	0.32%

Source: ECB.

Notes: Significant institutions at the highest level of consolidation for which common reporting (COREP) and financial reporting (FINREP) are available.

C: the value is suppressed for confidentiality reasons.

1) RoE and RoA are computed by dividing "net profit/loss" by, respectively, "equity" and "total assets" at the end of the corresponding reference period. The values of "net profit/loss", originally year-to-date, are annualised to increase the comparability of the ratios across quarters.

2) Returns figures may be based on different financial years. To increase consistency, if the end of the financial year is not 31 December, a linear projection of the figures has been made for each reporting period.

3) There are no significant institutions at the highest level of consolidation in Croatia and Slovakia.

4) As set out in the list of definitions of ITS data points, the numerator of the cost of risk indicator is adjustments in allowances for estimated loan losses during the relevant period (annualised). Those adjustments may be negative in certain circumstances.

Fig. 3.4. Key risk indicators by country for 2020

T04.02.2 Asset quality: non-performing loans and advances by country

(EUR billions; percentages)

Country (Q4 2020)	Loans and advances [2]	Non-performing loans and advances	Non-performing loans ratio
Belgium	450.72	7.89	1.75%
Bulgaria	C	C	C
Germany	2,792.34	33.43	1.20%
Estonia	33.49	0.40	1.19%
Ireland	369.86	12.43	3.36%
Greece	210.16	53.68	25.54%
Spain	2,381.57	69.67	2.93%
France	5,440.22	119.26	2.19%
Croatia [1]	-	-	-
Italy	1,872.10	77.34	4.13%
Cyprus	32.07	3.27	10.21%
Latvia	C	C	C
Lithuania	25.32	0.32	1.25%
Luxembourg	147.77	1.16	0.78%
Malta	16.54	0.57	3.46%
Netherlands	1,948.22	36.94	1.90%
Austria	475.40	9.99	2.10%
Portugal	148.46	8.13	5.48%
Slovenia	C	C	C
Slovakia [1]	-	-	-
Finland	505.29	7.66	1.51%
Total	**16,890.71**	**443.54**	**2.63%**

Source: ECB.

Notes: Significant institutions at the highest level of consolidation for which common reporting (COREP) and financial reporting (FINREP) are available.

C: the value is suppressed for confidentiality reasons.

1) There are no significant institutions at the highest level of consolidation in Croatia and Slovakia.

2) Loans and advances in the asset quality tables are displayed at gross carrying amount. In line with FINREP: i) held for trading exposures are excluded, ii) cash balances at central banks and other demand deposits are included.

Fig. 3.5. Assets quality for 2020

This is one of the asset quality tables data on loans, by country used for the study, from the Supervisory Banking Statistics, 4Q of 2020. The obtained results after processing, applying the InterCriteria Analysis method are in front of the following Table 3.5. and Table 3.6.

μ	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	0,8214	0,8929	0,3214	0,8214	0,9643	0,0714	0,8571	0,1071	0,7857	0,6429	0,1071	0,6429	0,5	0,5	0,4643	0,464	0,964	0,8571	0,5
2	0,8214	1	0,8571	0,4286	1	0,8571	0,1071	0,8214	0,1429	0,8214	0,6786	0,2857	0,6786	0,536	0,5357	0,5714	0,429	0,857	0,8929	0,536
3	0,8929	0,8571	1	0,3571	0,8571	0,9286	0,1071	0,8214	0,1429	0,75	0,6071	0,2143	0,6071	0,464	0,4643	0,5714	0,429	0,857	0,8214	0,464
4	0,3214	0,4286	0,3571	1	0,4286	0,3571	0,6071	0,3929	0,6429	0,4643	0,4643	0,7143	0,4643	0,393	0,3214	0,5714	0,5	0,357	0,4643	0,536
5	0,8214	1	0,8571	0,4286	1	0,8571	0,1071	0,8214	0,1429	0,8214	0,6786	0,2857	0,6786	0,536	0,5357	0,5714	0,429	0,857	0,8929	0,536
6	0,9643	0,8571	0,9286	0,3571	0,8571	1	0,0357	0,8929	0,0714	0,8214	0,6071	0,1429	0,6071	0,464	0,4643	0,5	0,5	0,929	0,8929	0,536
7	0,0714	0,1071	0,1071	0,6071	0,1071	0,0357	1	0,1429	0,8929	0,2143	0,3571	0,8214	0,3571	0,5	0,5	0,4643	0,536	0,036	0,1429	0,5
8	0,8571	0,8214	0,8214	0,3929	0,8214	0,8929	0,1429	1	0,0357	0,8571	0,5714	0,1071	0,5714	0,429	0,4286	0,3929	0,607	0,821	0,9286	0,643
9	0,1071	0,1429	0,1429	0,6429	0,1429	0,0714	0,8929	0,0357	1	0,1786	0,4643	0,8571	0,4643	0,607	0,6071	0,5714	0,429	0,143	0,1071	0,393
10	0,7857	0,8214	0,75	0,4643	0,8214	0,8214	0,2143	0,8571	0,1786	1	0,6429	0,25	0,6429	0,5	0,5	0,3929	0,607	0,75	0,9286	0,714
11	0,6429	0,6786	0,6071	0,4643	0,6786	0,6071	0,3571	0,5714	0,4643	0,6429	1	0,3214	1	0,857	0,7857	0,6071	0,393	0,679	0,6429	0,429
12	0,1071	0,2857	0,2143	0,7143	0,2857	0,1429	0,8214	0,1071	0,8571	0,25	0,3214	1	0,3214	0,464	0,4643	0,6429	0,429	0,143	0,1786	0,464
13	0,6429	0,6786	0,6071	0,4643	0,6786	0,6071	0,3571	0,5714	0,4643	0,6429	1	0,3214	1	0,857	0,7857	0,6071	0,393	0,679	0,6429	0,429
14	0,5	0,5357	0,4643	0,3929	0,5357	0,4643	0,5	0,4286	0,6071	0,5	0,8571	0,4643	0,8571	1	0,9286	0,6071	0,393	0,536	0,5	0,357
15	0,5	0,5357	0,4643	0,3214	0,5357	0,4643	0,5	0,4286	0,6071	0,5	0,7857	0,4643	0,7857	0,929	1	0,6071	0,321	0,536	0,5	0,286
16	0,4643	0,5714	0,5714	0,5714	0,5714	0,5	0,4643	0,3929	0,5714	0,3929	0,6071	0,6429	0,6071	0,607	0,6071	1	0,143	0,5	0,4643	0,25
17	0,4643	0,4286	0,4286	0,5	0,4286	0,5	0,5357	0,6071	0,4286	0,6071	0,3929	0,4286	0,3929	0,393	0,3214	0,1429	1	0,429	0,5357	0,893
18	0,9643	0,8571	0,8571	0,3571	0,8571	0,9286	0,0357	0,8214	0,1429	0,75	0,6786	0,1429	0,6786	0,536	0,5357	0,5	0,429	1	0,8214	0,464
19	0,8571	0,8929	0,8214	0,4643	0,8929	0,8929	0,1429	0,9286	0,1071	0,9286	0,6429	0,1786	0,6429	0,5	0,5	0,4643	0,536	0,821	1	0,643
20	0,5	0,5357	0,4643	0,5357	0,5357	0,5357	0,5	0,6429	0,3929	0,7143	0,4286	0,4643	0,4286	0,357	0,2857	0,25	0,893	0,464	0,6429	1

Table 3.5. Values of μ

v	1	2	3	4	5	6	7	8	9	10	11	12	131	4	15	16	17	18	19	20
1	0	0,1786	0,1071	0,6786	0,1786	0,0357	0,9286	0,1429	0,8929	0,2143	0,3571	0,8929	0,3571	0,5	0,5	0,5357	0,536	0,036	0,1429	0,5
2	0,1786	0	0,1429	0,5714	0	0,1429	0,8929	0,1786	0,8571	0,1786	0,3214	0,7143	0,3214	0,464	0,4643	0,4286	0,571	0,143	0,1071	0,464
3	0,1071	0,1429	0	0,6429	0,1429	0,0714	0,8929	0,1786	0,8571	0,25	0,3929	0,7857	0,3929	0,536	0,5357	0,4286	0,571	0,143	0,1786	0,536
4	0,6786	0,5714	0,6429	0	0,5714	0,6429	0,3929	0,6071	0,3571	0,5357	0,5357	0,2857	0,5357	0,607	0,6786	0,4286	0,5	0,643	0,5357	0,464
5	0,1786	0	0,1429	0,5714	0	0,1429	0,8929	0,1786	0,8571	0,1786	0,3214	0,7143	0,3214	0,464	0,4643	0,4286	0,571	0,143	0,1071	0,464
6	0,0357	0,1429	0,0714	0,6429	0,1429	0	0,9643	0,1071	0,9286	0,1786	0,3929	0,8571	0,3929	0,536	0,5357	0,5	0,5	0,071	0,1071	0,464
7	0,9286	0,8929	0,8929	0,3929	0,8929	0,9643	0	0,8571	0,1071	0,7857	0,6429	0,1786	0,6429	0,5	0,5	0,5357	0,464	0,964	0,8571	0,5
8	0,1429	0,1786	0,1786	0,6071	0,1786	0,1071	0,8571	0	0,9643	0,1429	0,4286	0,8929	0,4286	0,571	0,5714	0,6071	0,393	0,179	0,0714	0,357
9	0,8929	0,8571	0,8571	0,3571	0,8571	0,9286	0,1071	0,9643	0	0,8214	0,5357	0,1429	0,5357	0,393	0,3929	0,4286	0,571	0,857	0,8929	0,607
10	0,2143	0,1786	0,25	0,5357	0,1786	0,1786	0,7857	0,1429	0,8214	0	0,3571	0,75	0,3571	0,5	0,5	0,6071	0,393	0,25	0,0714	0,286
11	0,3571	0,3214	0,3929	0,5357	0,3214	0,3929	0,6429	0,4286	0,5357	0,3571	0	0,6786	0	0,143	0,2143	0,3929	0,607	0,321	0,3571	0,571
12	0,8929	0,7143	0,7857	0,2857	0,7143	0,8571	0,1786	0,8929	0,1429	0,75	0,6786	0	0,6786	0,536	0,5357	0,3571	0,571	0,857	0,8214	0,536
13	0,3571	0,3214	0,3929	0,5357	0,3214	0,3929	0,6429	0,4286	0,5357	0,3571	0	0,6786	0	0,143	0,2143	0,3929	0,607	0,321	0,3571	0,571
14	0,5	0,4643	0,5357	0,6071	0,4643	0,5357	0,5	0,5714	0,3929	0,5	0,1429	0,5357	0,1429	0	0,0714	0,3929	0,607	0,464	0,5	0,643
15	0,5	0,4643	0,5357	0,6786	0,4643	0,5357	0,5	0,5714	0,3929	0,5	0,2143	0,5357	0,2143	0,071	0	0,3929	0,679	0,464	0,5	0,714
16	0,5357	0,4286	0,4286	0,4286	0,4286	0,5	0,5357	0,6071	0,4286	0,6071	0,3929	0,3571	0,3929	0,393	0,3929	0	0,857	0,5	0,5357	0,75
17	0,5357	0,5714	0,5714	0,5	0,5714	0,5	0,4643	0,3929	0,5714	0,3929	0,6071	0,5714	0,6071	0,607	0,6786	0,8571	0	0,571	0,4643	0,107
18	0,0357	0,1429	0,1429	0,6429	0,1429	0,0714	0,9643	0,1786	0,8571	0,25	0,3214	0,8571	0,3214	0,464	0,4643	0,5	0,571	0	0,1786	0,536
19	0,1429	0,1071	0,1786	0,5357	0,1071	0,1071	0,8571	0,0714	0,8929	0,0714	0,3571	0,8214	0,3571	0,5	0,5	0,5357	0,464	0,179	0	0,357
20	0,5	0,4643	0,5357	0,4643	0,4643	0,4643	0,5	0,3571	0,6071	0,2857	0,5714	0,5357	0,5714	0,643	0,7143	0,75	0,107	0,536	0,3571	0

Table 3.6. Values of ν

The manifestation of a pronounced dependence between some of the observed indicators is due to both their economic nature and the way they are calculated. The manifestation of weak dependence between the indicators has its economic explanation. In the Statement of Income and Expenses of a credit institution, one indicator is income and the other is expense. Also, one of the criteria is from the Income and Expense Statement and the other from the institution's Balance Sheet asset, which has no relationship and does not generate an entry in the Income or Expense Statement.

3.4. Comparative analysis of the financial indicators of EU ıember states for the period 2020-2021

The analyzed indicators for the 4Q of 2021are the same as the indicators that we analyzed from the Supervisory Banking Statistic report for the 4 Q of 2020. There is a difference in indicators only for the following items in the 2020 report, the item net trading income exists as a result of changed reporting in 2021, it has been replaced by the more detailed breakdown of these revenues.

This article confirms the conclusions reached in the previous one. The starting data are different, consecutive financial years are analyzed, but the results obtained by means of the InterCriteria Analysis method show the same positive and negative relationships.

In conducting this research, presented in [5], data from the ECB's report - Supervisory Banking Statistics for the fourth quarter of 2021 were used.

The obtained results are presented in Table 3.7 and Table 3.8.

mu-table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1	0,8571	0,8214	0,5714	0,5357	0,7857	0,75	0,9643	0,0714	0,9286	0,1786	0,8214	0,9643	0,0357	0,9643	0,6786	0,6071	0,5	0,5714	0,9643	0,9286	0,5
2	0,8571	1	0,8929	0,5714	0,5357	0,7143	0,8214	0,8929	0,0714	0,8571	0,25	0,75	0,8214	0,1786	0,8214	0,5357	0,4643	0,6429	0,5	0,8929	0,8571	0,5
3	0,8214	0,8929	1	0,4643	0,6429	0,6071	0,7857	0,8571	0,1786	0,8214	0,2143	0,7143	0,7857	0,2143	0,7857	0,5	0,4286	0,6071	0,5357	0,8571	0,8214	0,5357
4	0,5714	0,5714	0,4643	1	0,1786	0,6429	0,3929	0,5357	0,4286	0,5	0,5357	0,3929	0,5357	0,4643	0,5357	0,5357	0,4643	0,5	0,4643	0,6071	0,5	0,3571
5	0,5357	0,5357	0,6429	0,1786	1	0,3929	0,6429	0,5	0,5357	0,5357	0,5	0,5714	0,5714	0,4286	0,5714	0,5	0,5714	0,5357	0,3929	0,5714	0,5357	0,5357
6	0,7857	0,7143	0,6071	0,6429	0,3929	1	0,6071	0,75	0,2143	0,7143	0,3929	0,75	0,75	0,25	0,75	0,6786	0,6071	0,4286	0,5714	0,75	0,7143	0,5
7	0,75	0,8214	0,7857	0,3929	0,6429	0,6071	1	0,7857	0,1786	0,8214	0,2857	0,7857	0,7857	0,2143	0,7857	0,5714	0,5	0,6071	0,4643	0,7143	0,8214	0,5357
8	0,9643	0,8929	0,8571	0,5357	0,5	0,75	0,7857	1	0,0357	0,9643	0,1429	0,8571	0,9286	0,0714	0,9286	0,6429	0,5714	0,5357	0,6071	0,9286	0,9643	0,5357
9	0,0714	0,0714	0,1786	0,4286	0,5357	0,2143	0,1786	0,0357	1	0,0714	0,8214	0,1786	0,1071	0,8929	0,1071	0,3929	0,4643	0,4286	0,3929	0,1071	0,0714	0,5
10	0,9286	0,8571	0,8214	0,5	0,5357	0,7143	0,8214	0,9643	0,0714	1	0,1071	0,8929	0,8929	0,1071	0,8929	0,6786	0,6071	0,5	0,6429	0,8929	1	0,5714
11	0,1786	0,25	0,2143	0,5357	0,5	0,3929	0,2857	0,1429	0,8214	0,1071	1	0,2143	0,2143	0,7857	0,2143	0,3571	0,4286	0,6071	0,2143	0,2143	0,1071	0,3214
12	0,8214	0,75	0,7143	0,3929	0,5714	0,75	0,7857	0,8571	0,1786	0,8929	0,2143	1	0,8571	0,1429	0,8571	0,7857	0,7143	0,3929	0,6786	0,7857	0,8929	0,6786
13	0,9643	0,8214	0,7857	0,5357	0,5714	0,75	0,7857	0,9286	0,1071	0,8929	0,2143	0,8571	1	0	1	0,7143	0,6429	0,4643	0,5357	0,9286	0,8929	0,5357
14	0,0357	0,1786	0,2143	0,4643	0,4286	0,25	0,2143	0,0714	0,8929	0,1071	0,7857	0,1429	0	1	0	0,2857	0,3571	0,5357	0,4286	0,0714	0,1071	0,4643
15	0,9643	0,8214	0,7857	0,5357	0,5714	0,75	0,7857	0,9286	0,1071	0,8929	0,2143	0,8571	1	0	1	0,7143	0,6429	0,4643	0,5357	0,9286	0,8929	0,5357
16	0,6786	0,5357	0,5	0,5357	0,5	0,6786	0,5714	0,6429	0,3929	0,6786	0,3571	0,7857	0,7143	0,2857	0,7143	1	0,9286	0,1786	0,6429	0,6429	0,6786	0,6071
17	0,6071	0,4643	0,4286	0,4643	0,5714	0,6071	0,5	0,5714	0,4643	0,6071	0,4286	0,7143	0,6429	0,3571	0,6429	0,9286	1	0,25	0,5714	0,5714	0,6071	0,5357
18	0,5	0,6429	0,6071	0,5	0,5357	0,4286	0,6071	0,5357	0,4286	0,5	0,6071	0,3929	0,4643	0,5357	0,4643	0,1786	0,25	1	0,2143	0,5357	0,5	0,2143
19	0,5714	0,5	0,5357	0,4643	0,3929	0,5714	0,4643	0,6071	0,3929	0,6429	0,2143	0,6786	0,5357	0,4286	0,5357	0,6429	0,5714	0,2143	1	0,5357	0,6429	0,8571
20	0,9643	0,8929	0,8571	0,6071	0,5714	0,75	0,7143	0,9286	0,1071	0,8929	0,2143	0,7857	0,9286	0,0714	0,9286	0,6429	0,5714	0,5357	0,5357	1	0,8929	0,4643
21	0,9286	0,8571	0,8214	0,5	0,5357	0,7143	0,8214	0,9643	0,0714	1	0,1071	0,8929	0,8929	0,1071	0,8929	0,6786	0,6071	0,5	0,6429	0,8929	1	0,5714
22	0,5	0,5	0,5357	0,3571	0,5357	0,5	0,5357	0,5357	0,5	0,5714	0,3214	0,6786	0,5357	0,4643	0,5357	0,6071	0,5357	0,2143	0,8571	0,4643	0,5714	1

Table 3.7. Values of μ

nu-table	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	0	0,1429	0,1786	0,4286	0,4643	0,2143	0,25	0,0357	0,9286	0,0714	0,8214	0,1786	0,0357	0,9643	0,0357	0,3214	0,3929	0,5	0,3929	0,0357	0,0714	0,5
2	0,1429	0	0,1071	0,4286	0,4643	0,2857	0,1786	0,1071	0,9286	0,1429	0,75	0,25	0,1786	0,8214	0,1786	0,4643	0,5357	0,3571	0,4643	0,1071	0,1429	0,5
3	0,1786	0,1071	0	0,5357	0,3571	0,3929	0,2143	0,1429	0,8214	0,1786	0,7857	0,2857	0,2143	0,7857	0,2143	0,5	0,5714	0,3929	0,4286	0,1429	0,1786	0,4643
4	0,4286	0,4286	0,5357	0	0,8214	0,3571	0,6071	0,4643	0,5714	0,5	0,4643	0,6071	0,4643	0,5357	0,4643	0,4643	0,5357	0,5	0,5	0,3929	0,5	0,6429
5	0,4643	0,4643	0,3571	0,8214	0	0,6071	0,3571	0,5	0,4643	0,4643	0,5	0,4286	0,4286	0,5714	0,4286	0,5	0,4286	0,4643	0,5714	0,4286	0,4643	0,4643
6	0,2143	0,2857	0,3929	0,3571	0,6071	0	0,3929	0,25	0,7857	0,2857	0,6071	0,25	0,25	0,75	0,25	0,3214	0,3929	0,5714	0,3929	0,25	0,2857	0,5
7	0,25	0,1786	0,2143	0,6071	0,3571	0,3929	0	0,2143	0,8214	0,1786	0,7143	0,2143	0,2143	0,7857	0,2143	0,4286	0,5	0,3929	0,5	0,2857	0,1786	0,4643
8	0,0357	0,1071	0,1429	0,4643	0,5	0,25	0,2143	0	0,9643	0,0357	0,8571	0,1429	0,0714	0,9286	0,0714	0,3571	0,4286	0,4643	0,3571	0,0714	0,0357	0,4643
9	0,9286	0,9286	0,8214	0,5714	0,4643	0,7857	0,8214	0,9643	0	0,9286	0,1786	0,8214	0,8929	0,1071	0,8929	0,6071	0,5357	0,5714	0,5714	0,8929	0,9286	0,5
10	0,0714	0,1429	0,1786	0,5	0,4643	0,2857	0,1786	0,0357	0,9286	0	0,8929	0,1071	0,1071	0,8929	0,1071	0,3214	0,3929	0,5	0,3214	0,1071	0	0,4286
11	0,8214	0,75	0,7857	0,4643	0,5	0,6071	0,7143	0,8571	0,1786	0,8929	0	0,7857	0,7857	0,2143	0,7857	0,6429	0,5714	0,3929	0,75	0,7857	0,8929	0,6786
12	0,1786	0,25	0,2857	0,6071	0,4286	0,25	0,2143	0,1429	0,8214	0,1071	0,7857	0	0,1429	0,8571	0,1429	0,2143	0,2857	0,6071	0,2857	0,2143	0,1071	0,3214
13	0,0357	0,1786	0,2143	0,4643	0,4286	0,25	0,2143	0,0714	0,8929	0,1071	0,7857	0,1429	0	1	0	0,2857	0,3571	0,5357	0,4286	0,0714	0,1071	0,4643
14	0,9643	0,8214	0,7857	0,5357	0,5714	0,75	0,7857	0,9286	0,1071	0,8929	0,2143	0,8571	1	0	1	0,7143	0,6429	0,4643	0,5357	0,9286	0,8929	0,5357
15	0,0357	0,1786	0,2143	0,4643	0,4286	0,25	0,2143	0,0714	0,8929	0,1071	0,7857	0,1429	0	1	0	0,2857	0,3571	0,5357	0,4286	0,0714	0,1071	0,4643
16	0,3214	0,4643	0,5	0,4643	0,5	0,3214	0,4286	0,3571	0,6071	0,3214	0,6429	0,2143	0,2857	0,7143	0,2857	0	0,0714	0,8214	0,3214	0,3571	0,3214	0,3929
17	0,3929	0,5357	0,5714	0,5357	0,4286	0,3929	0,5	0,4286	0,5357	0,3929	0,5714	0,2857	0,3571	0,6429	0,3571	0,0714	0	0,75	0,3929	0,4286	0,3929	0,4643
18	0,5	0,3571	0,3929	0,5	0,4643	0,5714	0,3929	0,4643	0,5714	0,5	0,3929	0,6071	0,5357	0,4643	0,5357	0,8214	0,75	0	0,75	0,4643	0,5	0,7857
19	0,3929	0,4643	0,4286	0,5	0,5714	0,3929	0,5	0,3571	0,5714	0,3214	0,75	0,2857	0,4286	0,5357	0,4286	0,3214	0,3929	0,75	0	0,4286	0,3214	0,1071
20	0,0357	0,1071	0,1429	0,3929	0,4286	0,25	0,2857	0,0714	0,8929	0,1071	0,7857	0,2143	0,0714	0,9286	0,0714	0,3571	0,4286	0,4643	0,4286	0	0,1071	0,5357
21	0,0714	0,1429	0,1786	0,5	0,4643	0,2857	0,1786	0,0357	0,9286	0	0,8929	0,1071	0,1071	0,8929	0,1071	0,3214	0,3929	0,5	0,3214	0,1071	0	0,4286
22	0,5	0,5	0,4643	0,6429	0,4643	0,5	0,4643	0,4643	0,5	0,4286	0,6786	0,3214	0,4643	0,5357	0,4643	0,3929	0,4643	0,7857	0,1071	0,5357	0,4286	0

Table 3.8. . Values of ν

There is a negative relationship between criterion 1 ("Net interest income") and criterion 14 ("Tax income or expenses") because one criterion is income and the other is an expense for the bank. The same conclusion can be drawn for criterion 8 ("Operating income") and criterion 9 ("Administrative expenses and impairment"). The analyzed data show a pronounced dependence between the criteria that are part of the Income Statement and their essence, with economic importance being one of the main reasons for the relationship between them. Also between the criteria from the Income Statement and assets from the Institution's Balance Sheet, as a consequence of these assets bringing a corresponding income for the banks.

3.5. Intelligent techniques for analysis of knowledge base of smart crop production

The main purpose of paper [2] is to propose an architecture of a knowledge base to be developed in order to automate the cultivation of crops. The architecture includes a two-layer data model and an applied layer model for a connection between them.

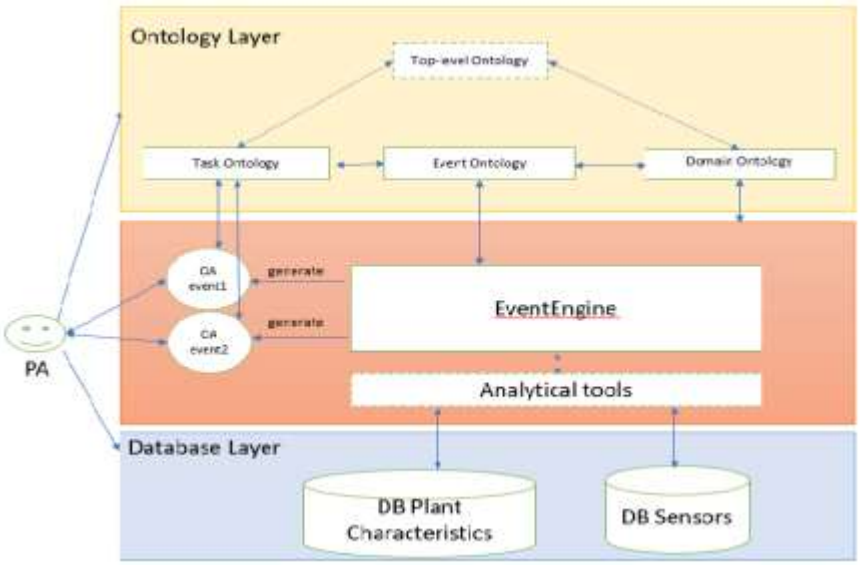

Fig. 3.9. The architecture of a knowledge base in plant agriculture

The proposed architecture for a knowledge base in the field of intelligent plant agriculture is designed to automate the work on growing different types of agricultural crops. One of the main tasks we have set ourselves is to make the process of cultivation more predictable, which will help farmers obtain better quality crops.

For the realization of the architecture, we have chosen Protégé for the ontologies, JaCaMo for the environment of the multi-agent system, Jason for the personal assistant, and Jade for the operational assistants.

CONCLUSION

The dissertation is devoted to the application of innovative, intelligent techniques for the analysis of processes in banking. The latest achievements in the field of designing highly efficient data processing algorithms are applied. The intelligent techniques used require the processing of large data streams, referring to all available information on the observed processes. In the dissertation, for the purposes of the analysis, mathematical modeling tools were used, such as InterCriteria Analysis (ICA), which is based on two mathematical formalisms: the algebraic apparatus of indexed matrices (IM), when the application of algebraic operations over matrices is required of different size and intuitionistic fuzzy sets (IFMs) as a mathematical tool for dealing with uncertainty. The research methodology in the dissertation includes the use of a numerical and experimental approach. The numerical approach was used in the implementation of the algorithms by means of computer calculation of the intelligent methods for analyzing the processes in banking. The experimental approach was used in the collection of data from observations of indicators characterizing the processes in banking. The aim of this dissertation is to analyze banking processes using modern methods from the field of intelligent systems. To achieve the set goal, six scientific tasks have been formulated. In the process of solving them, original results related to research of modern paradigms in the field of intelligent systems were obtained, using analytical and experimental models.

As a result of the conducted research, presented in this dissertation work, the following scientific-applied and applied results were achieved:

1. A critical analysis of the possibility of applying the multi-criteria decision-making method – “InterCriteria Analysis” in the analysis of processes in banking was conducted.

2. Intelligent techniques have been applied to analyze the mechanism of work of financial institutions in the EU, according to which the banking system functions.

3. An analysis of the activities of the participants in the financial system of the EU member states was carried out.

4. The financial indicators of eight selected EU member countries were analyzed.

5. A comparative analysis of the financial indicators of the banks in the selected EU member countries was carried out.

6. An original knowledge-based architecture with application in the field of intelligent plant breeding has been developed.

The achieved results of the analysis of the conducted studies are presented in a refereed scientific publication from the series *Lecture Notes in Networks and Systems of Springer International Publishing* and in the works of several international conferences, such as – *10-th International Conference on Intelligent Systems - IS'20, International Symposium on Bioinformatics and Biomedicine - BioInfoMed'20, International Conference Automatics and Informatics - ICAI'21, 11-th International Conference on Intelligent Systems - IS'22* and *International Workshop on Intuitionistic Fuzzy Sets and Generalized Nets - IWIFSGN'22*. The PhD thesis is structured in an introduction, three chapters and a conclusion, a declaration of originality of the obtained results and a bibliography.

GUIDELINES FOR FUTURE RESEARCH

The results obtained in the dissertation are applicable to solving a broader range of tasks related to the analysis of banking processes. This could be a guide for future research that will enrich the research area.

PUBLICATIONS ON THE TOPIC OF THE PHD THESIS

1. Danailova S., L. Doukovska, V. Atanassova - InterCriteria Analysis of the Financial System in the EU Countries. Proceedings of the 10-th International Conference on Intelligent Systems - IS'20, 28-30 August, Varna, Bulgaria, IEEE Xplore, ISBN: 978-1-7281-5456-5, ISSN: 1541-1672, DOI:10.1109/IS48319.2020.91999 43, pp. 183-186, 2020.

2. Stoyanova-Doycheva A., V. Ivanova, L. Doukovska, V. Tabakova, I. Radeva, S. Danailova - Architecture of a Knowledge Base in Smart Crop Production. Proceedings of the International Conference Automatics and Informatics – ICAI'21, 30 September-2 October 2021, Varna, Bulgaria, IEEE Xplore, 2021.

3. Danailova S., L. Doukovska, P. Vassilev - InterCriteria Analysis of the Global Competitiveness Report for the Financial System EU Countries, Proceedings of the 11-th International Conference on Intelligent Systems - IS'22, 12-14 October, Warsaw, Poland, IEEE Xplore, (in print).

4. Danailova S., L. Doukovska, A. Dukovski - InterCriteria Analysis of the Financial data for selected 8 EU Countries, Proceedings of the 11-th International Conference on Intelligent Systems - IS'22, 12-14 October, Warsaw, Poland, IEEE Xplore, (in print).

5. Danailova S., L. Doukovska, A. Dukovski - InterCriteria Analysis of the Supervisory Statistic Data for Selected 8 EU Countries During the Period 2020-2021, Chapter of Book: Uncertainty and Imprecision in Decision Making and Decision Support: New Advances, Challenges, and Perspectives, Series: Lecture Notes in Networks and Systems, Springer International Publishing, Switzerland, (in print).

DECLARATION OF ORIGINALITY

Hereby, I declare that this dissertation contains original research results obtained by me {with the support and assistance of my supervisor}. Results that have been obtained, described and/or published by other scientists are duly and extensively cited in the bibliography. This dissertation has not been applied for a degree at any other graduate school, university or scientific institute.

Sofia Signature:

(Slaviiana Danailova-Veleva)