

TDK THESIS

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DEVELOPMENT OF AN EXPERT SYSTEM TO EVALUATE RISKS OF LAUNCHING A STARTUP

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ABSTRACT

Launching a startup involves significant risk as majority of the companies go down in the first years of operation. The accurate risk assessment is crucial to the success of the venture. This thesis aims to address this challenge by developing a unified tool for risk evaluation specifically designed for startups in the IT industry in the European region.

As at the beginning of startup launching, there is no concrete data that can be analyzed, qualitative methods, including the Berkus, Risk Factor Summation, and Scorecard methods, are used to evaluate key factors that contribute to startup success, even before the company starts the operation. Fuzzy logic is employed to estimate the qualitative risk factors in light of the uncertain nature of the startup environment

Taking into consideration the methods mentioned above the unified tool – expert system, based on the fuzzy logic is developed as a Java web application to automate the risk assessment process. The proposed expert system employs various pre-money evaluation methods to determine a value of a startup and associated risk value.

To validate the developed expert system, several methods were used, resulting in a precise calculation logic with an accuracy rate of about 1, and both its precision and recall are around 100%. Comparison with other existing solutions demonstrates that the proposed expert system possesses some competitive advantages. Moreover, the expert system has the potential to be further improved as development continues.

The expert system for the risk evaluation for startup launching presented in this thesis is expected to help entrepreneurs make informed decisions when launching a startup by providing a reliable and accurate assessment of the risks involved. Future research could focus on providing more detailed descriptions of the output data generated by the expert system, developing new methods for calculating risks, and expanding the scope of the system to other industries and geographical regions. This expert system has practical applications in enabling entrepreneurs to better understand the risks involved in launching a startup, thereby improving their chances of success.

I. INTRODUCTION

The main aim of this chapter is to provide general information that covers the aim, objectives and importance of the work. It provides a short description of the present state of the problem and possible solutions. The chapter also presents the problem statement and the possible application of the developed expert system for the startup risk evaluation.

I.1 Problem statement

Nowadays, many entrepreneurs of different ages and experience launch startups. There are many impressive ideas, the implementation of which will make the world better. Only in the second half of 2021, there were approximately 4000 startup investments only in Europe (Europe: Startup investments 2015-2021).

Startup is a terrific opportunity to hit success or obtain huge losses. Risks are an indispensable element of any business, and it is essential to know them. Business risk analysis helps entrepreneurs prepare for problems in the preliminary stages of business development. If risks are approached systematically, the business will have protection from unexpected losses and the possibility to gain maximum effort.

The risk evaluation is usually based on numbers and predictions. It is difficult to evaluate the risk of a startup at the beginning of the project, as there is no concrete data that can be measured. However, it is still possible to evaluate the risks. There are many factors that should be considered for the evaluation process. Currently, there are many methods that help to assess the risks and success of a start-up. There are two main groups: qualitative and quantitative methods (ISO 21500:2021). The primarily used qualitative methods are:

- The Berkus valuation Method is a simple model for valuing a startup at the beginning. (Berkus, 2009).
- The Risk Factor Summation Method is a qualitative valuation method for companies that are just starting. This method values 12 risk factors and was introduced by Ohio TechAngels (Sarath, 2021).
- The scorecard method is also used to calculate the value of a startup. This method is used before investing in a startup (Payne, 2006).

There are many more methods of project evaluation that are based on quantitative factors:

- Book value evaluation;
- Venture Capital Method;

- Discounted cash flow;
- Liquidation value evaluation.

Currently, there are some tools that can evaluate the startup risk based on only one of the methods mentioned above. However, such a solution to the startup risk evaluation problem is far from perfect. There are several reasons for it. Firstly, the evaluation methods do not provide the possible risk value of the startup, the only output is the estimated value of the company. Secondly, quantitative-based evaluation methods are well applicable only to already existing companies but can hardly be relevant for startups. Thirdly, there is no unified tool that will provide the output based on the combination of methods, as the output of one method is insufficient for decision-making.

To solve the problem and have a chance to evaluate the risks of a startup launching, an expert system will be developed. The basis of the expert system is the three qualitative evaluation methods: the Berkus method, the scoring method, and the risk factor summation method. Use of several qualitative risk evaluation helps to make project development decisions in the initial stages which reduces losses of the startup. The output of an expert system will contain the merged value of calculated risk, which will help to make more confident decisions on startup launching.

I.2 Research objectives

The main aim of the thesis is to develop an expert system for evaluating the risks of a startup. The expert system should be based on three qualitative startup valuation methods. The specific objectives of the research are:

- 1) Development of an expert subsystem for evaluating the risks of a startup by using the Berkus Method.
- 2) Development of an expert subsystem for evaluating the risks of a startup by using the Risk Factor Summation Method.
- 3) Development of an expert subsystem for evaluating the risks of a startup by using the scoring method.
- 4) Development of a web application expert system for evaluating the risks of a startup based on the three subsystems.

I.3 Research steps

The following research steps will be implemented during the expert system development:

- Detailed study of risk assessment methods.
- Identify risk assessment factors based on the listed methods.
- Define input variables and their terms for the expert system.
- Study the types of membership functions.
- Determine the membership functions for input variables.
- Develop production rules of varying degrees of confidence.
- Develop an expert system with a single output variable.
- Test the developed expert system.

The research conceptual figure is presented on figure 1. The conceptual figure systematically explains the actions required during the current study.

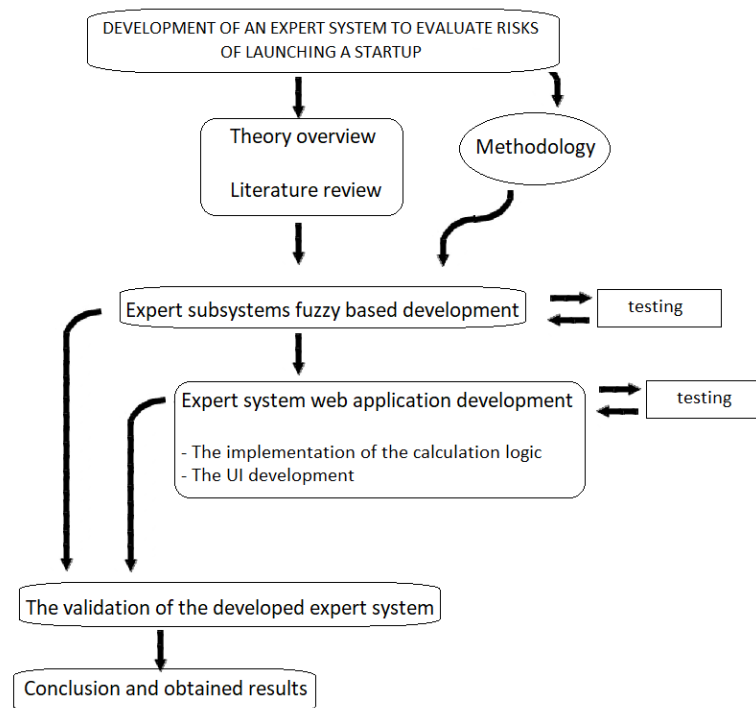


Figure 1. The research conceptual figure

I.4 Research Applications

The expert system, based on three qualitative evaluation methods, can be used for entrepreneurs for startup risk evaluation. The expert system can be the basis of the startup risk evaluation web application development. The risk evaluation expert system will help to:

- to make a more confident decisions on startup launching;

- to evaluate and prevent risks before launching the start-up, which will reduce potential costs;
- to evaluate the startup risks based on three qualitative methods and receive the merged risk evaluation.

This chapter outlined the general characteristics of the thesis work. It presented the main objectives of the study based on the problem to be solved, the research steps, and the research application of the work. The next chapter presents the theoretical background which is required for the development of an expert system for startup risk evaluation. This chapter also includes the literature review relevant to the topic. The focus of the literature review is the startup risk evaluation techniques and the development of expert systems for risk assessment.

II. THEORETICAL BACKGROUND AND LITERATURE REVIEW

The chapter gives the theoretical background which is needed to reach the goal of the thesis, to develop the expert system. That is why the chapter highlights issues such as the main aspects of the expert system, the basics of fuzzy logic and the fuzzy inference system, the definition of the startup and the description of the startup evaluation methods. Based on these theoretical data, the following chapters will describe the startup evaluation expert system development.

One important aspect of developing an expert system for evaluating the risks of launching a startup is the need to gather and analyze large amounts of data. This could include data on the startup's industry and market, as well as data on the startup's team and business model.

Another important aspect is the need to incorporate expert knowledge. This could include input from experienced entrepreneurs, investors, and industry experts, who can provide valuable insights into the risks and challenges that a startup may face. This information could be used to develop a set of risk factors and weightings that can be used to generate recommendations.

II.1 Expert systems

This part of the chapter provides a theoretical overview of the expert systems, the definition, structure, application of the systems, development stages. Later in chapter IV this information will be used as the basis for the development process.

II.1.1 Definition, paradigm and structure of an expert system

The main objective of the thesis is to develop a startup risk evaluation expert system. To begin with, it is necessary to understand what an expert system is. By definition, an expert system is a computer system that simulates the reasoning process of an expert in a certain subject area when solving a problem situation. The expert system can partially replace a specialist expert in solving a problem situation. Scientists engaged in artificial intelligence research began to develop expert systems in the 1970s, expert systems received commercial development in the 1980s (Jackson, 1998). An expert system is a smart computer application that operates with knowledge and inference procedures to tackle problems. The problem to solve has to be complex enough to require human experience. Such a definition was proposed by Professor Edward Feigenbaum of Stanford University (Adami, 1998). The expert systems can also be interpreted as complex software packages that accumulate the knowledge of specialists in specific subject areas and replicate this experience for consulting less qualified

users. The expert system is made for people working in the subject area but with low qualifications (Burakov, 2017).

The main distinctive feature of the expert system is that it can analyze and evaluate its reasoning and clarify its decisions (Hetem, 2000). The implementation of an expert system requires the extraction of knowledge from human experts (Tan & Kher, 2012). The expert system is a rule-based application that uses the prepared by expert knowledge base to provide the solution for the user. Common knowledge (a set of facts and rules of logical inference in a selected subject area) stored in the knowledge base, consists of various facts linked by IF-THEN. The rules connect the input data, which describes the problem, to be solved, with the output solution, the recommendation of the system (Tolun, 2016).

The general structural schema of the expert system is represented in figure 2. The most important part of any expert system is the knowledge base - a model of the behavior of experts in a certain field of knowledge. Facts, which are stored in the knowledge base, describe phenomena that are constant for a given subject area. The inference of the system and mapping of the data input with the suitable output is processed by the inference engine based on the rules from the knowledge base (Jackson, 1998).

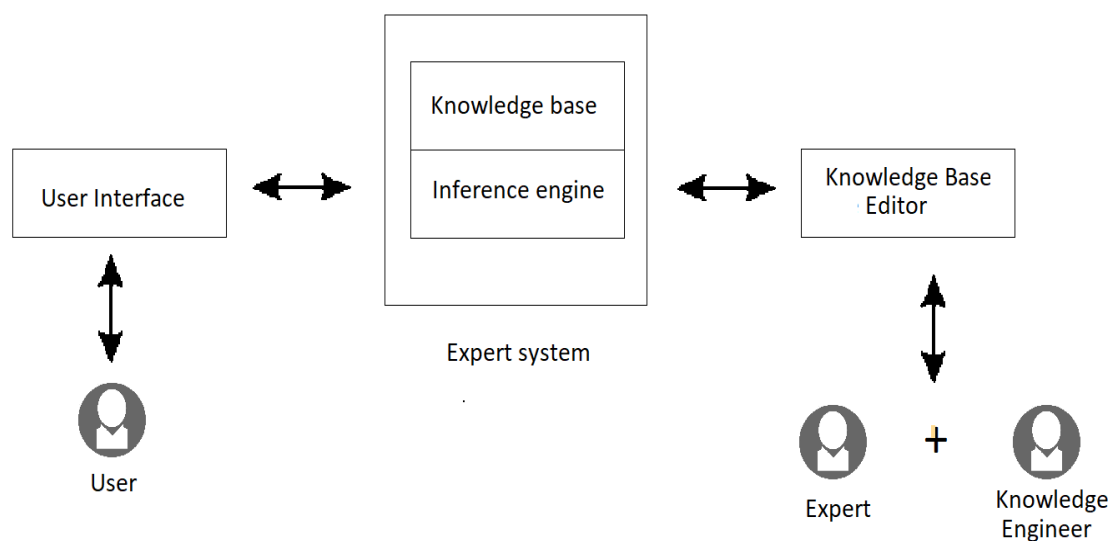


Figure 2. The general structural schema of the expert system (Korneev, 2001)

All expert systems have similar structures and ways of operation. The expert system can only operate in two modes. The modes are (Burakov, 2017):

- knowledge entry mode, in which an expert, with the help of a knowledge engineer, enters the information known to the expert (knowledge) about the subject area into the expert system knowledge base through the knowledge base editor;

- consultation mode, in which the user conducts a dialogue with the expert system, provides data about the current task and receives recommendations from the expert system.

Based on the two functional modes, the general operation process of the expert system has more detailed sub-actions and looks in the following way (Borisov, 2021):

- The system operates in the knowledge entry mode:
 - The experts prepare facts and rules which should be the basis for the expert system.
 - A knowledge engineer communicates with a human expert to gain knowledge.
 - The knowledge engineer enters the knowledge into the knowledge base.
 - The expert validates the expert system.
- The system operates in the consultation mode:
 - The user enters the problem description input data via user interface.
 - Based on the input information, set of rules, and knowledge the inference engine provides the recommended solution to the problem to the user.

II.1.2 Application and types of the expert systems

The scope of the expert system is closely related to its type and to the problem that the system should solve. The main categories of expert system applications are listed in table 1.

Table 1. Types of expert systems based on the problem (Borisov, 2021).

№	Category	Comment
1	Interpretation	The data meaning is being determined and results of the determination must be consistent and correct.
2	Diagnosis	The process of recognizing the state based on the available factors
3	Prediction	A reasonable description of the sequence of events, with the possibility of detecting new factors
4	Design	The process of creating new information about the object and the system (it is possible to exclude a professional from the design process).
5	Planning	A pre-planned order, sequence implementation of any program, work, event.

Continuation of table 1. Types of expert systems based on the problem (Borisov, 2021).

№	Category	Comment
6	Monitoring	Continuous notification of the status of the system, application or process.
7	Learning	User training, as well as self-learning of the system, both at the stage of acquiring knowledge and during the operation of the ES (replenishment of the ES knowledge base with new output chains)

In addition to the classification of expert systems depending on the application, there are others. For instance, expert systems can be classified into three groups, depending on how the expert system considers the time factor, the change in the environment in which the problem is solved:

- Static – developed in subject areas in which the knowledge base and interpreted data do not change over time.
- Quasi–dynamic - interpret situations that change with some fixed time interval.
- Dynamic – they work in conjunction with sensors of objects in real-time with the continuous interpretation of incoming data to the system (Hetem, 2000).

As for the application of the expert system, the key aim of any such system is to provide a solution for some specific problem based on the provided information and the problem area. From the user's point of view expert systems can be used for process optimization, information management, performance evaluation, planning and scheduling, monitoring and control and many other purposes (Borisov, 2021).

The most widely known expert systems are used for computations and diagnosis. Some of the examples are mentioned below:

- WolframAlpha is a knowledge base and a group of computational algorithms, which together form an intelligent computational knowledge engine (About Wolfram|Alpha, 2015).
- MYCIN is the most well-known diagnostic system that is designed to diagnose and monitor the condition of a patient with meningitis and bacterial infections (Buchanan, 1984).
- IBM Watson is an IBM supercomputer capable of understanding questions formulated in natural language and finding answers to them in a database (Ferrucci, 2012).

II.1.3 Advantages and limitations of expert systems

As expert systems model the behavior of a human expert, the process of data processing and decision-making are becoming more automated. Several advantages appear because of automatization and optimization (Kiryanov, 2021):

- Increased accessibility. The expert system proposed the problem solution based on the set of knowledge provided by the expert. The knowledge base could be updated at any time, which would increase the quality of the output solution.
- Cost reduction. The usage of the expert system cuts the expense of consulting with the experts.
- Performance improvement, fast response. Thanks to the automated data processing process, expert systems have high performance.
- Increased reliability. The expert system proposed the problem solution based on the set of knowledge provided by the expert. The knowledge base could be updated at any time, which would increase the quality of the output solution.
- Explanation. The main key feature of the expert system is that it can analyze and review its reasoning and explain its decisions.
- Specificity. The expert system provides solutions to a problem in a narrow area of specialization.

Apart from advantages, the expert systems have several limitations which should consider (Borisov, 2021):

- Regularly the decision-making process happens under conditions of uncertainty, so the expert system should have the ability to operate under such a condition. Because of this, the system is not able to make a response in an extraordinary situation.
- As the expert system is constructed to solve a narrow special problem, it cannot be reused for other purposes.
- The knowledgebase has to be constructed carefully as any error would lead to the wrong recommendation and system maintenance can lead to high costs.

II.1.4 Expert system development

The process of development an expert system is a crucial and requires high attention. During the development the system operates in the knowledge entry mode, the main steps are mentioned in the previous subchapter. The development process has the following stages:

1) Selection of a problem area (Burakov, 2017). This activity precedes the development of a specific expert system. The first stage contains the following sub-activity:

- identification of the problem area of the problem;
- finding an expert and appointing a team of developers;
- determining a preliminary approach to solving the problem;
- analysis of development costs and profits;
- preparation of a detailed development plan.

2) The prototype development (Burakov, 2017). The current stage starts only after the problem is identified and the preparational activities are finished.

During this step, an incomplete version of the system is developed. The main purpose is focused on verifying the correctness of coding facts, knowledge and reasoning strategies of experts. The standard volume of the prototype is several dozen rules. The general stages of prototype creation are presented in table 2.

Table 2. The steps of prototype development (Dorogov, 2012)

№	The stage name	Main activities
1	Problem identification	Task clarification Planning the progress of prototype development Identification of necessary resources (time, people, machines), sources of knowledge (books, methods, additional experts) Search and analysis of similar expert systems Defining goals Definition of classes of solved problems Introduction and training of all members of the development team Creating an informal description of the problem
2	Acquisition (extraction) of knowledge	Obtaining the most complete possible understanding of the subject area and methods of decision-making in this area.
3	The knowledge structuring	Development of an informal description of knowledge about the subject area in the form of tables, graphs, plain text, which reflects the basic concepts and relationships between the concepts of the subject area. Definition of terminology, basic concepts and relations between them; structures of input and output data and decision-making strategies.
4	The knowledge formalization	The development of the knowledge base

Continuation of table 2. The steps of prototype development (Dorogov, 2012)

№	The stage name	Main activities
5	Prototype implementation	Development of a software package demonstrating the viability of the approach
6	Testing	Identification of errors in the implementation of the prototype and development of recommendations for fine-tuning the system to the industrial version

3) Development of an industrial expert system

This stage also contains prototype development. However, compared to the previous one this prototype presents a complete version of the system. As the knowledge and the inference logic are already verified in the previous stage, there is a possibility to continue the development process.

Several types of prototypes are created at different steps of development. All of them are equally important during the development process (Dorogov, 2012):

- Demonstration prototype. The system solves part of the tasks and demonstrates the viability of the approach. It includes several dozen rules, concepts, etc.
- Research prototype. The system solves most tasks but is unstable in operation and not fully tested. It contains several hundred rules and concepts.
- A working prototype. The system reliably solves all problems using real examples, but there is no optimization of resources.
- Industrial system. The system provides a high-quality solution while minimizing the resources consumed.
- Commercial system. The system, on top of everything else, is well-documented and equipped with a service.

4) Evaluation of the system

This stage is extremely important, as it provides the evaluation of the developed system. To estimate the quality of the system, the expert system is being tested in terms of performance criteria. Usually, it requires the involvement of other experts. The following criteria are taken into account (Berry & Hart, 2007):

- User evaluation (clarity and transparency of the system, ease of use).
- Criteria of invited experts (evaluation of tips and solutions, comparing them with their solutions, evaluation of the subsystem of explanations).
- Developer criteria:
 - implementation efficiency;

- performance;
- response time;
- design;
- the breadth of domain coverage;
- consistency of the knowledge base;
- number of deadlocks;
- analysis of the sensitivity of the program to minor changes in the representation of knowledge, weighting factors in the mechanisms of logical inference.

5) System implementation and future maintenance.

After the development and successful evaluation, the expert system can be put into operation. However, continuous maintenance is required in case of any problem detection or need for further system updates.

II.2 Fuzzy Logic

Fuzzy set theory is basis of fuzzy logic. It is a set of flexible mathematical approaches that are used to handle incomplete information and the unharness of situations (Barot, 2017). Fuzzy set theory and logic offer a means of measuring the level of uncertainty caused by inaccuracy and ambiguity. This part describes important aspects of fuzzy logic.

II.2.1 Definitions and main aspects

Fuzzy logic is based on the calculus of statements of a special kind – fuzzy statements. A statement is called fuzzy if its measure of truth is $T(A) \in [0; 1]$, compared to the standard statements for which $T(A) \in \{0, 1\}$ (Zadeh, 1965).

Fuzzy logic operates with fuzzy sets. A fuzzy set is a mathematical construct that represents a group of objects that have a degree of membership to the set. The definition of the fuzzy set is the following fuzzy set $\bar{A}$ is a pair $\langle A, \mu \rangle$, where A is the carrier of the fuzzy set $\bar{A}$, and μ is the membership function, such that $\mu: A \rightarrow (0; 1]$. Thus, $\bar{A}$ is a set of pairs $(a, \mu(a))$, $a \in A$, where the number $\mu(a)$ is – a measure of the membership of element a to the fuzzy set $\bar{A}$ (Zadeh, 1965).

A fuzzy set is obtained from an ordinary set by replacing a characteristic property with a membership function: if $A = \{a \mid P(a)\}$ – an ordinary (clear) set, then $\bar{A} = \{a \in A \mid \mu(a)\}$ – fuzzy set.

There are also fuzzy variables in the fuzzy set theory. A fuzzy variable N is called a triple $\langle N, U, X \rangle$, where N is the name of the fuzzy variable, X is some fuzzy set, and U is the

universe on which it is defined. Terms or linguistic variables are named finite sets of fuzzy variables.

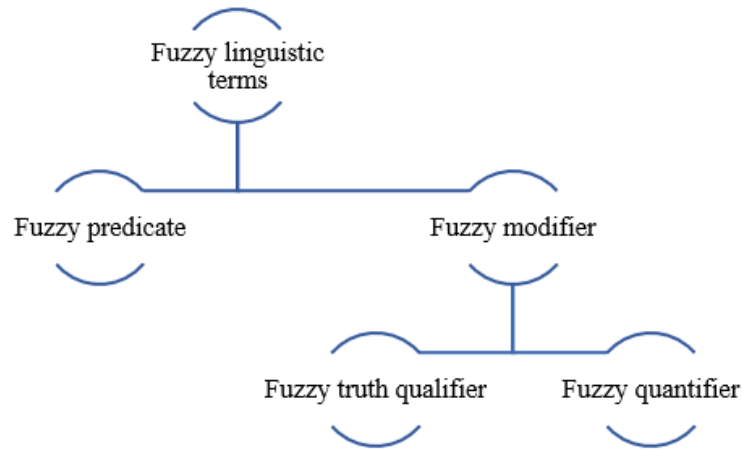


Figure 3. The structure of fuzzy predicate (Burakov, 2017)

As shown in figure 3, fuzzy linguistic terms have two components. The fuzzy predicate provides some description that can be defined in a fuzzy way. Typical examples are expensive, old, rare, dangerous, good, etc. The modifier is needed to change the meaning of the predicate. Examples are quite true, false, very false for the truth qualifier and many, few, almost, all, usually for the quantifier.

The following part contains some examples of the fuzzy predicate comparing it to the predicate in classical logic.

A predicate in classical logic: “ x is a woman” or “ z is P ”. Here x and z are variables, and “woman” and “ P ” are crisp sets. It can also be written as “ $woman(x)$ ” and “ $P(z)$ ”.

A fuzzy logic predicate contains ambiguity: “ e is cheap” or “ y is old”. The terms “cheap”, “old” are fuzzy terms. Therefore, the sets “cheap (e)”, “old (y)” are fuzzy sets.

II.2.2 Fuzzy statements, predicates and logical operators

As mentioned above, the difference between a fuzzy statement and an ordinary statement $\tilde{A}$ is that its truth measure belongs to the segment $[0; 1]$ in contrast to an ordinary statement, the true measure of which always belongs to a two-element set $\{0, 1\}$.

Similarly, the predicate $\tilde{P}(x_1, \dots, x_n)$ is called fuzzy if $\tilde{P}$ is fulfilled: $X_1 \times \dots \times X_n \rightarrow [0; 1]$, that is, each combination of the values of the predicate variables $(x_1 \dots, x_n)$ corresponds to the number $\mu \in [0; 1]$.

Fuzzy logical operators are applied to fuzzy statements, like the logical operators defined in the calculus of statements (Burakov, 2017).

- Fuzzy negation: $\tilde{B} = \neg \tilde{A} \Leftrightarrow T(\tilde{B}) = 1 - T(\tilde{A})$;
- Fuzzy conjunction: $\tilde{C} = \tilde{A} \wedge \tilde{B} \Leftrightarrow T(\tilde{C}) = \min(T(\tilde{A}), T(\tilde{B}))$;
- Fuzzy disjunction: $\tilde{C} = \tilde{A} \vee \tilde{B} \Leftrightarrow T(\tilde{C}) = \max(T(\tilde{A}), T(\tilde{B}))$;
- Fuzzy implication: $\tilde{C} = \tilde{A} \rightarrow \tilde{B} \Leftrightarrow (\neg \tilde{A} \vee \tilde{B}) \Leftrightarrow T(\tilde{C}) = \max(1 - T(\tilde{A}), T(\tilde{B}))$;
- Fuzzy equivalence: $\tilde{C} = \tilde{A} \leftrightarrow \tilde{B} \Leftrightarrow ((\tilde{A} \rightarrow \tilde{B}) \wedge (\tilde{B} \rightarrow \tilde{A})) \Leftrightarrow T(\tilde{C}) = \min(\max(1 - T(\tilde{A}), T(\tilde{B})), \max(1 - T(\tilde{B}), T(\tilde{A})))$.

II.2.3 Fuzzy Inference System

Fuzzy logical inference, like ordinary logical inference, relies on inference rules, which are modified rules of modus ponens and modus tollens.

The fuzzy inference system includes the following components:

- 1) Sets of input and output linguistic variables.
- 2) A set of fuzzification rules. The rules are used for converting the results of measurements of numerical quantities into the values of specified linguistic variables.
- 3) A set of fuzzy implications.
- 4) A composition rule that allows determining the measure of the truth of all conclusions based on the establishment of the truth of the premises.
- 5) An aggregation rule that allows us to receive the value of the "generalized term" for each output variable.
- 6) The defuzzification rule, that is, the rule for determining the numerical values of output variables based on the established values of the output linguistic variables.

All fuzzy inference algorithms (for example, the most common algorithms of Mamdani, Larsen, Sugeno and Tsukamoto) produce fuzzy inference using these steps, differing only in the implementation of the rules of composition, aggregation and defuzzification (Burakov, 2017).

Mamdani Fuzzy Inference System was originally proposed by Ebrahim Mamdani in the 1980s. The Mamdani Inference System includes the following steps (Mamdani, 1974):

- A set of fuzzy rules must be determined.
- The input membership function is used to define fuzzy input.
- The combining the fuzzy inputs, based on the set rules, the strength rule is established.
- The strength of the rule and the membership function of output are combined to determine the consequences of the rules.
- The defuzzified output distribution is received.

Another inference system is System Sugeno fuzzy inference, also known as Takagi-Sugeno-Kang fuzzy inference. It uses singleton output membership functions which can be defined as either constant or a linear function (Lai, Tsen, 2013).

Compared to the Mamdani system, the defuzzification process of the Sugeno system has higher efficiency of computation. The reason for this is the usage of the weighted sum of a few data points (Sugeno, 1985).

Evaluating a rule of the system generates both a rule weight and an output level:

- The output level of a rule could be either linear function of the input values or a constant.
- The current rule strength is defined by the previous rule.
- The output of each rule is the weighted output level. This is the product of the rule output level and the rule strength.

II.2.4 Membership Function

The membership function in fuzzy sets is an expanded version of the indicator function used in classical sets. It is utilized in fuzzy logic to signify the extent of truth by extending valuation. While probabilities are often mistakenly interchanged with degrees of truth, they are different because fuzzy truth indicates membership in indistinctly defined sets, rather than the probability of an event or situation (Zadeh, 1965).

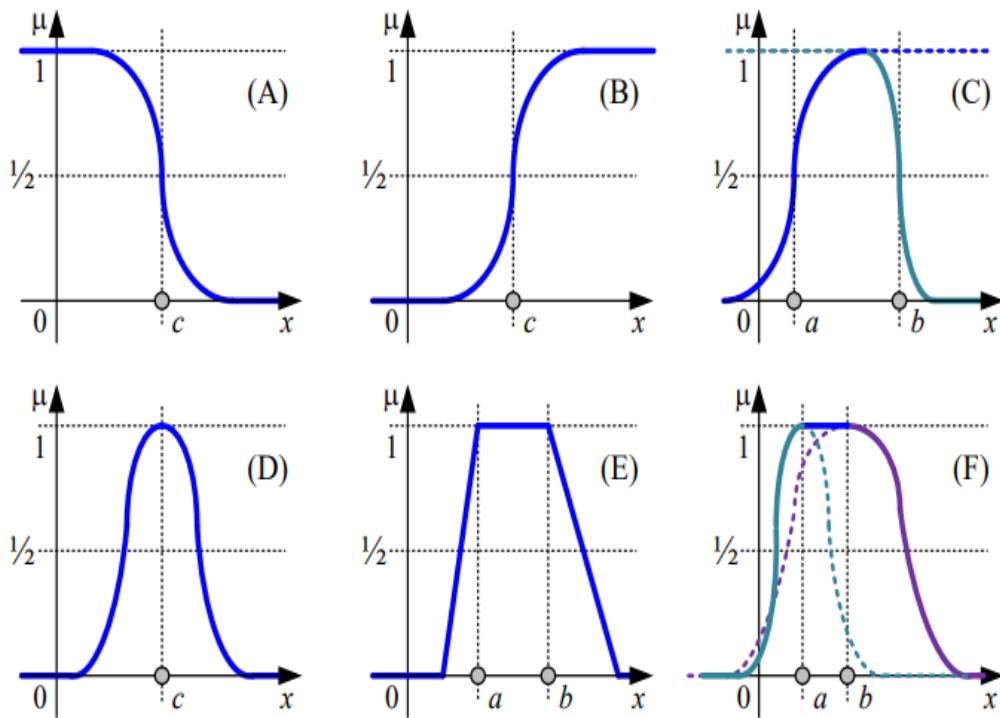


Figure 4. The typical membership functions (Zadeh, 1965)

The figure 4 shows the typical membership functions used when setting fuzzy values:

$$(A). \text{ Z-function} \quad \frac{Z(x; c, \alpha) = 1}{1 + \exp(\alpha(x - c))}$$

$$(B). \text{ S- function} \quad \frac{S(x; c, \alpha) = 1}{1 + \exp(-\alpha(x - c))}$$

$$(C). \text{ P- function} \quad P(x; a, b, \alpha, \beta) = S(x; a, \alpha) * Z(x; b, \beta)$$

$$(D). \text{ G- function} \quad G(x; c, \alpha) = \exp\left(\frac{-(x - c)^2}{2 \alpha^2}\right)$$

(Gaussian function)

$$(E) \text{ T- function} \quad T(x; a, b, \alpha, \beta) = \begin{cases} 0, x \in [a - \alpha; b - \beta] \\ \frac{x - a + \alpha}{\alpha}, a - \alpha \leq x \leq a \\ 1, x \in [a; b] \\ \frac{b - x + \beta}{\beta}, b < x \leq b + \beta \end{cases}$$

$$(F) \text{ LR-function} \quad LR(x; a, b, \alpha, \beta) = \begin{cases} G(x; a, \alpha), x < a \\ 1, x \in [a; b] \\ G(x; a, \beta), x > b \end{cases}$$

The S-function and the Z-function are used to represent fuzzy rays, i.e., fuzzy intervals with an upper or lower bound equal to infinity. P-function, T-function and LR-function are used to represent a fuzzy segment $[a; b]$. The G-function is used to represent the fuzzy number c . When the equality $a = b = c$ is fulfilled, the T-function and the LR-function also represent a fuzzy number (Burakov, 2017).

II.2.5 Fuzzy Logic in Expert Systems

To deal with the major challenge for expert systems to handle uncertainty, fuzzy logic should be used in expert systems (Jain & Gupta, 2018). The application of fuzzy logic in expert systems can lead to significant changes in the final solutions. For example, fuzzy rules can help to model the uncertainty of the input data by using such linguistic variables as lovely, acceptable, awful, bad. The unification of fuzzy logic and the expert system can improve the performance and reliability of the expert system in decisions making process. The usage of principles of fuzzy logic with an expert system constructs a fuzzy expert system that can use human experience and knowledge with inaccurate, controversial and uncertain data (Khan, 2011).

II.3 Startup

This thesis aims to develop a tool for evaluating the risk associated with startups. To understand the concept of a startup, it is important to first define the term. A startup can be defined as a process for initiating a new job or action, or as an early-stage company. These companies often possess unique characteristics and innovative ideas, products, or services. The main goal of these companies is to succeed in the market and achieve growth. Many entrepreneurs have innovative ideas and attempt to capitalize on them by starting a company (Akkaya, 2019).

Despite their diversity in form, startups share certain common characteristics. As with any newborn or young company, startups face challenges in achieving their potential and growth. Some of these characteristics include:

- Startups have a limited or no history of previous operations.
- Startups have small revenues or no revenues at all.
- Startups often require private equity.
- A large number of startups do not survive and fail.

According to several studies, a significant number of startups fail, particularly in their early stages. Failure rates are particularly high among these companies. Less than thirty percent of young companies remain on the market and achieve success (Vesper, 1980).

One of the reasons for this high failure rate is that startups operate in conditions of significant uncertainty. It is often unknown who their customers are or what their product should be. Additionally, the current environment is becoming increasingly unpredictable and unstable, making it difficult to predict the future. Planning and forecasting are only accurate when based on a long, stable history of activity and a relatively stable environment, which startups do not have (Ries, 2011).

II.4 Start-up Evaluation

To reduce the uncertainty and to receive the value of the startup and prevent business failure, evaluation should be done before launching a startup. The significance of accurate assessment during the initial stages of a startup is closely related to the present-day economy. (Akkaya, 2019).

Some risks which a company may face are necessary for business. To gain success, entrepreneurs should mitigate risks that can be managed and accept risks that cannot be avoided.

To have the ability to mitigate the risks, firstly they should be known, which can be gained by the evaluation.

The risk evaluation is usually based on numbers and predictions. It is difficult to evaluate the risk of a startup at the beginning of the project, as there is no concrete data that can be measured. However, it is still possible to evaluate the risks. There are many factors that should be considered for the evaluation process. Currently, there are many methods that help to assess the risks and success of a start-up. There are two main groups: qualitative and quantitative methods (ISO 21500:2021).

II.4.1 Quantitative Methods of Startup Evaluation

Quantitative methods are sometimes called post-money methods as these methods it is already needed to calculate the revenue or the losses of the startup. All quantitative evaluation methods apply to already operating companies but can hardly be relevant for a startup. Currently, there is no doubt that traditional valuation techniques are not completely satisfied for assessing the value of a startup (Dehghan-Eshratabad & Albadvi, 2018). Key problem limiting the usage of quantitative techniques is the lack of qualitative information, which provides collected calculations. Due to the fact, that startup is a young company, there is no information about the past revenue or cash flow and the market data could also be limited (Dusatkova & Zinecker, 2016). However, some modifications of the traditional quantitative methods could be used for the startup evaluation even if the data is limited:

- The real option method (ROM) is based on the Black & Scholes financial option theory. Based on the model, managers have only two options put or call. Decisions are made in a fuzzy environment, and uncertainty is reduced as more information is obtained. The ROM could be used for the startup evaluation, as it considers strategic flexibility (Smit & Trigeorgis, 2012). However, this model has some critical issues, which limit its usability of the model. (Milanesi et al., 2013). Currently, ROM is not used as a real evaluation technique (Frykman & Tolleryd, 2012).
- The venture capital method (VCM) evaluates the future value of a company based on the net present value of future cash flows in the most likely scenario. The definite time horizon and an interest rate are also taken into account. (Smith et al., 2011). The method considers risk and uncertainty of the business during the evaluation process. The VCM calculates a startup's value by evaluating future cash flows by comparing the company and the market through various approaches. The VCM is a widely used method, but it

also has limits such as the usage of discount rates and many possible scenarios (Goldenberg & Goldenberg, 2009).

- Another method that could be used for the startup evaluation is the modified Discount Cash Flow method (Festel et al., 2013). The problem with this method is the lack of startup historical data. However, the analysis could be based on future prediction and not on historical data. To evaluate the discount rate and startup's value the specific business sector should be analyzed. (Damodaran, 2009).

II.4.2 Qualitative Methods of Startup Evaluation

The qualitative evaluation methods, also known as the pre-money methods, are suitable for startup evaluation. Usage of the methods helps to make project development decisions in the initial stages which reduce losses of the startup. The general advantage of the qualitative methods is that the evaluation of the qualitative features gives the result in a quantitative format (Montani 2020).

II.4.2.1 The Berkus Valuation Method

Dave Berkus, the American venture capitalist and angel investor, created the Berkus model, which provided a chance to react to the risks of startup companies and to meet their financial targets. The Berkus Method of evaluation is an early-stage pre-money valuation method. Current method is usually applied at a starting point of startup evaluation. The method quantifies a startup's value by assessing qualitative qualities instead of quantitative ones.

As shown in table 3, each key factor should be estimated at up to half million Euros, which allows young startups to reach a total value for two and half million. The method is based on the fact that the elements of risk reduction are estimated in monetary terms. (Berkus 2009, Hura 2022).

Table 3. Example of Berkus Method (Berkus, 2009).

Characteristic	Add to Pre-money Valuation, in million of €
Quality management team	0 - 0.5
Sound idea	0 - 0.5
Working prototype	0 - 0.5
Quality board of directors	0 - 0.5
Product rollout or sales	0 - 0.5

The main benefits of the Berkus valuation method are (Berkus, 2009):

- The Berkus method is a straightforward model which is based on qualitative aspects. This is a traditional way to evaluate pre-money startups.
- The method provides a quick rough evaluation.
- The Berkus model is easily modifiable.
- The method considers corporate governance and risk management topics.

The main limitations are (Berkus, 2009):

- The method is too simplified.
- The method ignores financial risk.

II.4.2.2 The Risk Factor Summation Method

The Risk Factor Summation Method considers particular risk factors, which help to evaluate future risks in a more complex way. The risk factor summation method uses an initial value of a startup as a basis for the future company's valuation. This base value is changed based on twelve risk factors. The evaluated startup is compared to other startups and risks are estimated as higher or lower risk. (Sarath 2021, Hura 2022)

Here are the steps of The Risk Factor Summation Method implementation:

- 1) Determine the average industry valuation of the company.
- 2) In the first step, the average industry pre-money valuation of the target startup should be obtained.
- 3) In the second step, the 12 risk factors should be considered based on the industry.
- 4) In the third step, all risk factors should be assigned with ratings as shown in table 4.

Table 4. The rating in the risk factor summation method (Sarath 2021)

Rating	Risk rationale	Adjustment to pre-money valuation, in thousands of €
+2	Extremely positive mitigation	+ 500
+1	Positive mitigation	+ 250
0	Neutral	+/- nothing
-1	Negative mitigation	- 250
-2	Extremely negative mitigation	- 500

After the risk factors assessment is done, the adjustment to the average pre-money valuation of the startup should be made.

- 5) In that last step, the average industry pre-money valuation should be added to the adjusted sum.

Advantages of the method (Sarath 2021):

- This method is quite simple compared to others.
- The method takes into account factors that are not covered by the Berkus and Scorecard methods.

The disadvantages of the risk summation method are the following (Sarath 2021):

- The method takes into account only the negative consequences of the startup risks.
- The method equally weights all risk factors.
- The method relies only on the limited group of startups, which were chosen for comparison.

II.4.2.3 The scorecard valuation method

The scorecard valuation method, also known as the Bill Payne method, helps investors to calculate an average value of a startup before the company gets any income. This method uses weighted percentages and market data to determine the average value of the company.

In this method, the target startup which is looking for investments is compared with other similarly funded startups. The method compares companies based on several factors like the stage of development, business sector, and geographic location. (Payne, 2006). The evaluation example is shown in figure 5.

Here are the steps of scorecard valuation method implementation:

- Determine the average industry pre-money valuation of the company. The region of the company and the industry of startup operation should be taken into account. (Hura 2022)
- Determine the ranges for the key factors.
- Evaluate the target company based on the other companies in the sector and the region.

Criterion	Weight	Target company	Factor
Team	30%	X	$= 0,3 * x$
Size of opportunities	25%	X	$= 0,25 * x$
Product / technology	15%	X	$= 0,15 * x$
Competitive enviro.	10%	X	$= 0,10 * x$
Sales / Marketing	10%	X	$= 0,10 * x$
The need for more funding	5%	X	$= 0,05 * x$
Others	5%	X	$= 0,05 * x$
Total			The sum of all factors

Figure 5. Example of evaluation using the Scorecard method (Hura 2022)

II.4.3 Risk factors for startup

Three qualitative methods are chosen as the basis for the future expert system development. These methods are the Berkus method, the risk summation method and the scorecard method. The following tables 5-7 contain a list of success factors, outlined in each of the methods and the comments on each factor.

Table 5. Main factors estimated by the Berkus method.

№	The factor	Comment
1	Quality of the idea	The company has an exciting business idea.
2	Existence of a prototype	Customers are drawn to the company's product or prototype.
3	Team quality	The company has formed an excellent management team.
4	Strategic partnerships	The company has defined partner relationships with other market players
5	Introduction and product sales	The company already has some income from sales

Table 6. Main factors estimated by the risk summation method

№	The factor	Comment
1	Risk of the Management	Is the company operated by an experienced management team?
2	Stage of the business	At which stage is the startup? How successful is the stage?
3	Political risk	Is the political situation taken into account by the company management? How can the political situation affect the company?
4	Supply chain or manufacturing risk	Is the supply chain and manufacturing well organized?
5	Sales and marketing risk	Does the company have a sales and marketing strategy?
6	Capital raising risk	Does the company need to raise capital?
7	Competition risk	Does the company have a competitive advantage?
8	Risk of Technology	Does the company have any technological advantages or problems?
9	Risk of Litigation	Does the company have any law-connected risks?
10	International risk	Does the company interact with the international market?
11	Risk of Reputation	Does the company have a policy for maintaining the company's reputation?
12	Exit value risk	Does the company have well-prepared exit strategy?

Table 7. Main factors estimated by the scorecard method

№	The factor	Comment
1	Strength of the Management Team: 0-30%	Is the team complete? Experienced? Coachable?
2	Size of the Opportunity: 0–25%	Quantifiable target market \$
3	Product/Technology: 0–15%	Is IP well defined? Traction?
4	Competitive Environment: 0–10%	Barriers to entry?
5	Marketing/Sales Channels/Partnerships: 0–10%	Key beta testers? Key partners?
6	Need for Additional Investment: 0–5%	Is there any need for additional investment?
7	Other: 0–5%	Geographical factors?

II.5 Literature Review

In recent years, there has been an increasing interest in the development of expert systems for startup risk evaluation. These systems are designed to help entrepreneurs make informed decisions by providing them with relevant information about the potential risks and opportunities associated with their startups. This literature review will examine the current state of startup risk evaluation and the development of expert systems for risk assessment.

Arias-Aranda and others (2010) presented a fuzzy rule-based model for the simulation of the business firm's behavior. The proposed model is the basis for the fuzzy expert system. The usage of fuzzy logic in the research gives a possibility to increase the accuracy and quality of decisions provided as the output of the expert system, which is adaptive to various scenarios.

Salamzadeh and Kawamorita (2015) studied and conceptualized the phenomenon of a startup, the life cycle and the challenges that it might face. Based on the research, startups not only operate under conditions of high uncertainty, but also the startup development stages are messy and highly uncertain.

Ibraigheeth and Fadzli (2019) applied the fuzzy logic approach to the development of the risk evaluation expert system. The study found that the implementation of fuzzy logic into the expert system development process allows one to deal with the real data from a huge number of software projects and estimates the risk probability of software projects, at any stage of development, based on the critical success factors.

In one of his works, Akkaya (2019) described and analyzed the existing startup evaluation methods. According to the research, a startup exists in terms of uncertainty, and the evaluation cannot be based on quantitative features like the revenue, book or liquidation value

or cash flow. Based on the output of the research it is preferable to evaluate risk of the startup with help of pre-money valuation methods.

Spoiala (2020) reviewed the idea of early risk detection and management. According to the study at the early stages, startups face high uncertainty and have high rates of failure as a result only a small amount of them become successful and influential. In this research the risks which pharmaceutical companies may face were defined, classified and evaluated. Based on the research, the early risk detection and implementation of the risk strategy had an impact on the minimization of risk probability and diminution of risk impact.

Montani, Gervasio, and Pulcini (2020) made a systematic review of the most used methods for startup valuation. Mentioned methods provide an opportunity to define the state of the art and future trends of a startup. The results of the research showed that currently there is no single method that would give the perfect evaluation of the company. It is connected to the fact that all methods have significant limits. The paper names three aspects that should be considered during the evaluation: attention to future forecasts, usage of the probabilities to consider various future opportunities and attention to the specific business model of a startup.

Rismadhanti and Prasetyo (2020) conducted a case study on the evaluation of S-MART, a new startup from Bandung, using the Berkus and scorecard methods. The methods were chosen as the most suitable for the S-MART case. The evaluation was based on the assessment of 5 main factors which can be divided into 10 subcategories of different weights. The article gives an example of the usage of the Berkus and Scorecard methods. However, such factors as the market was not considered. Such an assumption can be crucial in the evaluation process.

The idea of how to cope with potential problems of wrong evaluation is presented by Hura (2022). According to the research, different methods should be combined to consider as many factors as possible. The study gives an overview of business valuation methods and gives a list of the key factors which should be considered during the valuation process.

Taking everything into account, considerable studies have been done related to startup evaluation. The best way of a startup evaluation is the usage combination of pre-money valuation methods. The evaluation should preferably be done in the early stages of the company's life, as it gives the possibility to prevent possible risks. The usage of fuzzy logic is the way to cope with the conditions of uncertainty during the startup evaluation.

In conclusion, this literature review suggests that there is an increasing interest in the development of expert systems for evaluating the risks of startup launching. Studies have demonstrated that these systems can provide entrepreneurs with relevant and personalized

information on potential risks and opportunities associated with their startup ventures, by utilizing historical data and machine learning techniques.

This chapter considers the theoretical aspects of the thesis. The main aim is to develop an expert system for startup evaluation. The theoretical part has a definition, description of the main paradigm, and types of expert systems. The usage of the expert system for startup evaluation is a good way to automatize the evaluation process. The chapter also has the theoretical aspects of a startup and a description of startup evaluation methods. For future work, the pre-money qualitative evaluation methods will be used. As a startup company operates in terms of uncertainty fuzzy logic will be used in the expert system development. The theoretical chapter considers the basics of fuzzy logic, the definition of main terms and rules, and the inference system. This chapter gives the theoretical background for future development. The next chapter outlines the methodological foundations of the work.

III. METHODOLOGY

Startups always operate under conditions of uncertainty (Ries, 2011). Uncertainty, in turn, is the absence or incompleteness of the definition of concepts or an insufficient amount of information about something. A startup company does not have quantitative data on which it would be possible to forecast the future and calculate possible risks. This is the reason for using qualitative methods of risk assessment, for the building of an expert system for startup risks evaluation.

The current chapter provides the methodologies which will be used during the following expert system development.

III.1 Data collection

The development of an expert system requires expert consultation and the gaining of expert knowledge. But the current expert system is based on the three theoretical startup evaluation methods. As the methods are well structured and defined, the knowledge-gaining step is not needed.

However, data collection and analysis are required to determine the dependencies between the success factors, defined by the evaluation methods, and the success value of the startup. The following research methods are used for the data collection:

- Analyze publicly available data sources.
- Analyze online resources such as search engines, social media platforms, and online forums.
- Analyze secondary data such as financial statements, case studies, or other publicly available information.

III.2 Development of the expert subsystem

The development of the expert subsystems will be based on fuzzy logic. Fuzzy logic relies on a form of approximate reasoning that measures the data uncertainty by utilizing imprecise values (Sinha & Makkar, 2021). This technique will allow the expert system to operate under conditions of uncertainty with qualitative data.

The list of the objectives with the methods is presented in table 8, the description of chosen evaluation methods can be found in chapter II, II.3.1.2. Qualitative Methods of Startup Evaluation. The combination of the methods covers different sides of a startup development like management, marketing, investments, competition, strategy, technology, product, and

others. An evaluation based on a comprehensive assessment will more clearly and reasonably determine the level of risk for a startup launch.

Table 8. Methodology

No	Objectives	Methods	Factors	Tools & Techniques
1	Development of the expert subsystem for evaluating the risks of a startup by using the Berkus Method	The Berkus Method	Quality management team Sound idea Working prototype Quality board of directors Strategic relationships Product rollout or sales	Data Analysis Fuzzy Logic Technique
2	Development of the expert subsystem for evaluating the risks of a startup by using the Risk Factor Summation Method	The Risk Factor Summation Method	Management Stage of the business Legislation/Political risk Manufacturing risk Sales and marketing risk Funding/capital raising risk Competition risk Technology risk Litigation risk International risk Reputation risk Potential lucrative exit	MATLAB version R2018a Fuzzy Logic Toolbox 2022 HTML Java CSS
3	Development of the expert subsystem for evaluating the risks of a startup by using the scoring method	The scoring method	Strength of the management team Size of the opportunity Product/technology Competitive environment Marketing/sales channels/partnerships Need for additional investment	IntelliJ IDEA 2022.3.1 Tom cat server

III.3 Development of the web application expert system based on the subsystems

In the process of work, a comprehensive expert system consisting of three subsystems will be developed. The expert system has multiple input and a single output. Input consists of

qualitative evaluation of the factors used in the methods; the output contains the risk level of the evaluated startup. For the expert system to work correctly, the input data will be subject to data analysis, based on this analysis, the result of the startup evaluation will be synthesized.

The final web application expert system will be developed as a web application in IntelliJ IDEA 2022.3.1 with use of Tom cat server. The predevelopment of fuzzy-based subsystems will be done via the MATLAB version R2018a programming environment using the fuzzy logic toolbox, which provides apps for analyzing, designing, and simulating fuzzy logic systems. It is possible to tune membership functions and rules of a fuzzy inference system from data (Fuzzy Logic Toolbox 2022).

- The objective: Development of the web application expert system based on the subsystems.
- Methods: All methods are mentioned in table 8.
- Factors: All factors mentioned above are mentioned in table 8.
- Tools and techniques: Questionnaire (for the data input), Fuzzy Logic Technique, HTML, Java, CSS, IntelliJ IDEA 2022.3.1, Tom cat server.

III.4 Validation of the expert system

Any newly created system has to be validated as it is an essential part of any development process. Without the validation, the expert system can contain some errors and would not be appropriate for usage. For the validation of the developed expert system following methods will be used:

- Precision;
- Specificity;
- Sensitivity;
- Accuracy;
- Comparative analysis;
- User interface evaluation;

The first four methods are needed to validate the correctness of calculations and the possible error rate. The fifth method is required to compare current expert systems with already existing ones. The sixth valuation technique is needed to develop a convenient and easily understandable user interface.

This chapter outlines the methodology which is needed for the successful development of an expert system. The next chapter 4 provides a detailed description of the expert system

development process. The general requirements and assumptions relevant to the development are also mentioned in the chapter. Based on the objective, the development includes the implementation of three fuzzy logic-based expert subsystems and one unified web application expert system. The second part of the chapter contains the validation process of the developed system.

IV. EXPERIMENTAL RESULTS

Based on the information in the previous chapters, an expert system for evaluating the risks of a startup launch is developed. This system considers three pre-money valuation methods to assess various significant aspects of the business and evaluate the startup risks more comprehensively. The current chapter explains the detailed process of developing this expert system. In the beginning, the general requirements for the fuzzy expert system and their application for chosen methods are described. As not all general requirements can be fulfilled, the chapter's second part contains necessary assumptions. The next parts of this chapter contain the data analysis and the development process.

IV.1 General requirements for a fuzzy expert system

Expert system development has several basic steps, which must be fulfilled for the successful implementation of the expert system. A detailed description is provided in chapter II.1.5, but as the system is based on fuzzy logic there are some minor specific requirements.

IV.1.1 Application and assumptions of general requirements to the selected assessment methods

Before developing the expert system, certain assumptions must be taken into consideration as not all the general steps mentioned earlier may be directly relevant to the current development. The methods chosen for risk evaluation have already been well-established, which may allow for certain general steps to be simplified. Table 9 shows the assumptions for developing an expert system for pre-money risk evaluation of startups in the IT industry in Europe.

The 1st assumption is that developing an expert system is based on three pre-money evaluation methods: the Berkus method, the risk factor summation method, and the scorecard method. Each method already contains a set of factors that should be estimated. The methods were developed to evaluate the startups, and young companies with limited or no available data for the analysis. These pre-money risk evaluation methods do not depend on historical data. So, data collection and analysis are not needed. Although historical data could prove useful in comparing various evaluation results, it is not pertinent to the current development. The data-collecting step does not apply to the expert systems based on Berkus, the risk factor summation and scorecard methods. The methods assume that all factors are equally important, and it is unnecessary to define which factor has a bigger impact on the general success of the business.

The 2nd assumption is that risk factor summation and scorecard methods generate two values: the adjusted sum, which is an intermediate result of the methods, and the result, which is the total of the adjusted sum and the average pre-money valuation in the current industry and region. It is possible to calculate the risk value by solely estimating the adjusted sum without analyzing the result, which makes the average pre-money valuation in the current industry and region unnecessary for the expert system's operation. This assumption is critical as there may be a lack of information regarding the pre-money valuation in the current industry and region.

The 3rd assumption is that in calculating the adjusted sum using the scorecard method, supplementary data is necessary. This calculation involves multiplying the evaluated factors with weights that are not yet distinctly defined. These weights, which depend on the industry and region, will be determined following data collection and analysis. It has been decided to develop an expert system for the IT (Information Technology) industry in Europe.

The 4th assumption is that by defining the fuzzy sets for each method, the method descriptions must be considered, as each method already has pre-determined scales for the factors to be evaluated. For the Berkus method, each factor should be assessed on a scale ranging from 0 to 500. The fuzzy set can be defined as not applicable, really bad, bad, normal, good, or really good. In the risk factor summation method, each factor can only be evaluated as extremely negative, negative, neutral, positive, or extremely positive. The scale falls between - 2 and 2. As for the scorecard method, factors are estimated as much worse than average, worse than average, the same as average, better than average, or much better than average.

The 5th assumption is that all factors in the methods are considered equal. Therefore, it has been determined that the membership functions for each fuzzy set will have a triangular value.

The 6th assumption is based on the data available; the expert system will be developed for the IT industry in the European region.

Table 9. Assumptions for Developing an Expert System for Pre-Money Risk Evaluation of Startups in the IT Industry in Europe

Assumption	Description
1st	The expert system is based on three pre-money evaluation methods: the Berkus method, the risk factor summation method, and the scorecard method. The methods do not require historical data and assume that all factors are equally important.
2nd	The risk value can be calculated by estimating the adjusted sum without analyzing the result. The average pre-money valuation in the current industry and region is not necessary.
3rd	Supplementary data is necessary to calculate the adjusted sum using the scorecard method. Weights for each factor will be determined following data collection and analysis.
4th	The fuzzy sets for each method are pre-determined scales for the factors to be evaluated. The Berkus method uses a scale ranging from 0 to 500 with fuzzy sets of not applicable, really bad, bad, normal, good, or really good. The risk factor summation method uses a scale between -2 and 2 with fuzzy sets of extremely negative, negative, neutral, positive, or extremely positive. The scorecard method uses fuzzy sets of much worse than average, worse than average, the same as average, better than average, or much better than average.
5th	Membership functions for each fuzzy set will have a triangular value as all factors in the methods are considered equal.
6th	The expert system will be developed for the IT industry in the European region.

Once the expert system has been implemented, it will undergo testing, evaluation, and commentary by experts and entrepreneurs. Based on their feedback, any necessary modifications will be made.

IV.1.2 Development of a fuzzy logic-based expert system for risk evaluation of startup launching

As table 10 shows, the first step is the identification of the area of the problem to be solved. This step is already completed as the problem, which the expert system should solve, is already defined by the aim and sub-objectives of the work. The problem area is the development of the fuzzy logic-based expert system for the risk evaluation of the startup launching, moreover, the expert system is based on three startup qualitative valuation methods.

The second step is the collection of data which will be used in the expert system. The data on evaluation methods and factors should be collected for future analysis and the identification of patterns. This step is needed to clarify the dependencies between the factors and the success of the startup. The important remark is that the collected data is industry, region, and time-dependent. This will affect the expert system and thus will be industry and region dependent.

The third step is to define the fuzzy sets for each factor based on the data collected. For example, market size can be defined as small, medium, or large. The methods used for the risk evaluation should also be considered, as sometimes the fuzzy sets could be fully or partly defined in the methods.

The fourth step contains the definition of the membership functions for each fuzzy set. The membership function is used to determine the degree of membership of a factor to a particular fuzzy set. This step is also closely related to the analysis of chosen evaluation methods. Since the degree of membership could have already been determined for the selected methods.

The fifth step is the development of the rules for the expert system based on the selected evaluation methods. These rules will be used to evaluate the risks of launching a startup based on the input data. The output data should contain the risk value.

The sixth step is the implementation of the expert subsystem in Matlab using the fuzzy logic toolbox. This includes defining the fuzzy sets, membership functions, and rules.

The seventh step is the test and validation of the subsystem. This step will result in necessary adjustments to improve the system's accuracy.

The eighth step is the development of a web application fuzzy expert system based on all evaluation methods and the validation of the general system.

Table 10. Steps for developing a fuzzy logic-based expert system for risk evaluation of startup launching

Step	Description	Output
1	Identification of the problem area, statement of the problem to be solved.	Development of the fuzzy logic-based expert system for the risk evaluation of the startup launching, moreover, the expert system is based on three startup qualitative valuation methods.
2	Collection of data that will be used in the expert system.	Data on evaluation methods and factors were collected for future analysis and pattern identification.
3	Define the fuzzy sets for each factor based on the collected data.	Fuzzy sets are defined for each factor.
4	Definition of the membership functions for each fuzzy set.	Membership functions are defined for each fuzzy set.
5	Development of rules for the expert system based on the selected evaluation methods.	Rules developed for evaluating the risks of launching a startup based on input data.

Continuation of table 10. Steps for developing a fuzzy logic-based expert system for risk evaluation of startup launching

Step	Description	Output
6	Implementation of the expert subsystem in MatLab using the fuzzy logic toolbox.	A fuzzy expert system implemented in MatLab.
7	Test and validation of the subsystem.	Adjustments made to improve system accuracy.
8	Development of a web application fuzzy expert system based on all evaluation methods and validation of the system.	The validated fuzzy expert system deployed to help entrepreneurs evaluate the risks of launching a startup.

Once the system is validated, it can be deployed to help entrepreneurs evaluate the risks of launching a startup.

IV.1.3 Development of the fuzzy expert subsystem

The startup risk evaluation expert system is the combination of three subsystems, each based on one of the chosen evaluation methods. The input for each subsystem consists of the evaluation of relevant factors, and the output is the risk value calculated based on fuzzy inference. The final output of the global system is the average risk value calculated based on the outputs of the subsystems. This section presents a detailed description of the system development process.

The initial phase in developing the fuzzy expert system is to establish linguistic (or fuzzy) variables (parts of fuzzy sets) for each evaluation method. This stage is conducted by referring to the method descriptions and the assumptions made in the preceding chapter.

The next stage of the fuzzy expert system's development is to define the membership functions for the input and output values of the fuzzy sets. As previously stated, all factors are considered equally important and the membership functions for each fuzzy set should be triangular.

The following step is to establish rules for generating the output value. The Sugeno system is utilized in the creation of the fuzzy expert system. As a result, the output values are not a range but constant.

IV.2 Expert subsystem based on the Berkus method

The Berkus method has five evaluation factors, each of which can be evaluated on a scale between 0 and 500. So, for each factor, the fuzzy set is defined on $X_i = [0, 500]$. All parameters should be evaluated impartially and objectively. The set of possible verbal meanings for all factors is the same and is determined as $T_i = \{\text{not applicable, really bad, bad, normal, good, really good}\}$.

IV.2.1 Fuzzy variables

As mentioned in the assumptions, the fuzzy variables for the current subsystem are equal to the risk factors, defined in the Berkus method. The fuzzy variables are the following:

- 1) Quality of the idea. Does the company have an exciting business idea? How well would you describe/evaluate your business idea?
- 2) Existence of a prototype. Does the company have exciting technology or a solid product or prototype that attracts customers? How well would you describe/evaluate the product/technology?
- 3) Team quality. Has the company assembled an excellent management team? How well would you describe/evaluate your management team?
- 4) Strategic partnerships. Does the company have defined partner relationships with other market players? How would you evaluate the existing strategic partnership?
- 5) Introduction and product sales. Does the company have any revenue from sales? How would you evaluate this parameter?

The expert system based on the Berkus method has five input variables and one output variable, the estimated risk value.

IV.2.2 Definition of membership functions of fuzzy sets

The membership functions for each fuzzy set have the triangle value, functions are defined in the following way:

Not applicable $\lambda_i(x) > 0, \lambda_{na}(x) = \text{trimf} [-100 \ 0 \ 100]$

Really bad $\lambda_i(x) > 0, \lambda_{rb}(x) = \text{trimf} [0 \ 100 \ 200]$

Bad $\lambda_i(x) > 0, \lambda_b(x) = \text{trimf} [100 \ 200 \ 300]$

Normal $\lambda_i(x) > 0, \lambda_n(x) = \text{trimf} [200 \ 300 \ 400]$

Good $\lambda_i(x) > 0, \lambda_g(x) = \text{trimf} [300 \ 400 \ 500]$

Really good $\lambda_i(x) > 0, \lambda_{rg}(x) = \text{trimf} [400 \ 500 \ 600]$

The plot of the membership functions is shown in figure 6, the fuzzy set is defined on $X_i = [0, 500]$ and the term is following $T_i = \{\text{not applicable, really bad, bad, normal, good, really good}\}$.

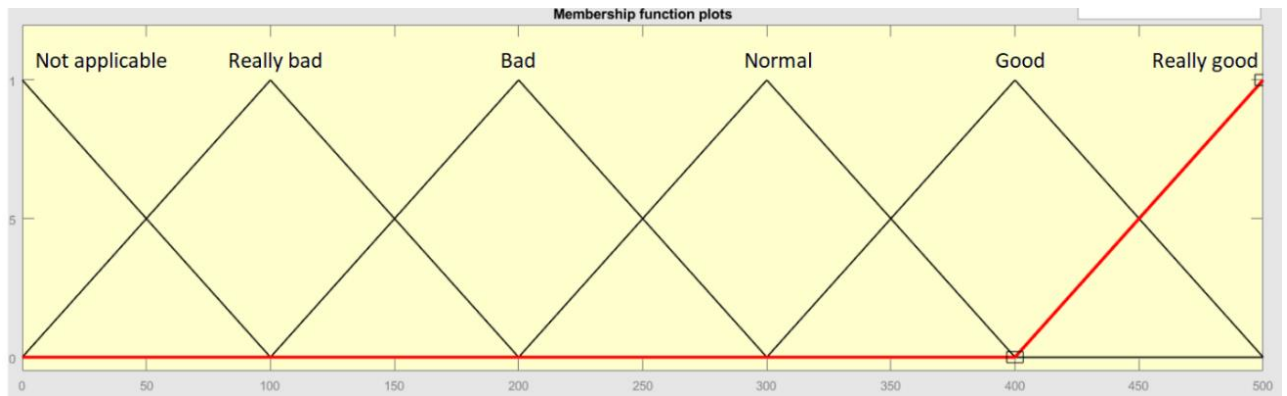


Figure 6. The membership function plot for the expert system based on the Berkus method

The output of the Berkus method is the sum of all evaluated factors. After the evaluation of the factors, the output is calculated in the following way (1).

$$Output_{Berkus} = \sum_{i=1}^5 x_i \quad (1)$$

where x_i - the numerical representation of each evaluated factor

An example of the Berkus method calculations is shown in table 11.

Table 11. The example of the Berkus method

Input		Output
The factor	Evaluation value	
Quality of the idea	30	1225
Existence of a prototype	129	
Team quality	500	
Strategic partnerships	225	
Introduction and product sales	341	

IV.2.3 Risk value determination

According to the possible values of the factor evaluation, the possible output values for the Berkus method are in the range [0, 2500].

The output of the expert system based on the Berkus method is the risk level, which has three values: low risk, medium risk and high risk. It is decided to divide the output value of the Berkus method into 3 equal ranges and assign each range to one of the possible risk levels, as shown on figure 7.



Figure 7. The risk values for the Berkus method

IV.2.4 Rules determination

A total number of rules for the fuzzy expert system can be calculated by the formula (2).

$$N_{rules} = N_t^{N_x} \quad (2),$$

where N_{rules} – total number of rules, N_t – total number of terms, N_x – total number of factors.

In the case of the Berkus method, the number of rules equals to

$$7776 = 6^5.$$

The rules are represented on figure 8. Here each term value is replaced by a numeric number for easier representation, $T_i = \{\text{not applicable, really bad, bad, normal, good, really good}\}$ equals to $T = \{0,1,2,3,4,5\}$. The output of the rules is determined by figure 7.

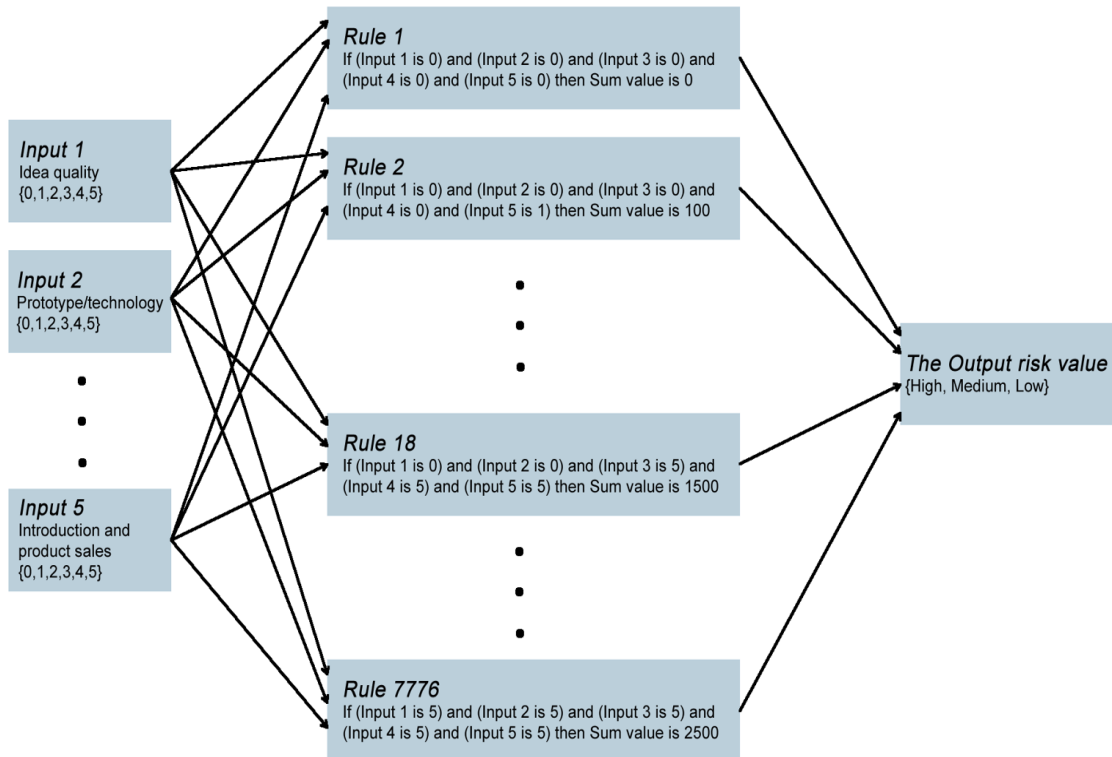


Figure 8. The rules for the Berkus method

IV.3 Expert subsystem based on the risk factor summation method

The risk factor summation method has twelve evaluation factors, each of which can be evaluated on a scale between -2 and 2. So, for each factor, the fuzzy set is defined on $X_i = [-2, 2]$ with step 1. All parameters should be evaluated impartially and objectively. The set of possible verbal meanings for all factors is the same and is determined as $T_j = \{\text{extremely negative, negative, neutral, positive, extremely positive}\}$.

IV.3.1 Fuzzy variables:

As mentioned in the assumptions, the fuzzy variables for the current subsystem are equal to the risk factors, defined in the risk factor summation method. The fuzzy variables are the following:

- 1) Risk of the management. Is the company operated by an experienced management team? How would you evaluate this parameter?
- 2) Stage of the business. How could you evaluate the current stage of business?
- 3) Political risk. Is the political situation taken into account by the company management? How can the political situation affect the company?
- 4) Supply chain or manufacturing risk. Is the supply chain and manufacturing well organized?
- 5) Sales and marketing risk. Does the company have a well-defined sales and marketing strategy?
- 6) Competition risk. Does the company have a competitive advantage?
- 7) Capital raising risk. Does the company need to raise capital?
- 8) Risk of Technology. How would you estimate a company's technological advantages or problems?
- 9) Risk of Litigation. How would you estimate a company's any law-connected risks?
- 10) International risk. How would you estimate the company's interactions with the international market?
- 11) Risk of Reputation. Does the company have a policy for maintaining the company's reputation?
- 12) Exit value risk. Does the company have a well-prepared exit strategy?

The expert system based on the risk factor summation method has twelve input variables and one output variable, the estimated risk value. According to the assumption the risk value is calculated based on the adjusted sum.

IV.3.2 Definition of membership functions of fuzzy sets

The membership functions for each fuzzy set have the triangle value, functions are defined in the following way:

Extremely negative $\lambda_i(x) > 0, \lambda_{en}(x) = \text{trimf}[-3 - 2 - 1]$

Negative $\lambda_i(x) > 0, \lambda_n(x) = \text{trimf}[-2 - 1 0]$

Neutral $\lambda_i(x) > 0, \lambda_{neut}(x) = \text{trimf}[-1 0 1]$

Positive $\lambda_i(x) > 0, \lambda_p(x) = \text{trimf}[0 1 2]$

Extremely positive $\lambda_i(x) > 0, \lambda_{ep}(x) = \text{trimf}[1 2 3]$

The plot of the membership functions is shown in figure 9, the fuzzy set is defined on $X_i = [-2, 2]$ and the term is following $T_j = \{\text{extremely negative, negative, neutral, positive, extremely positive}\}$.

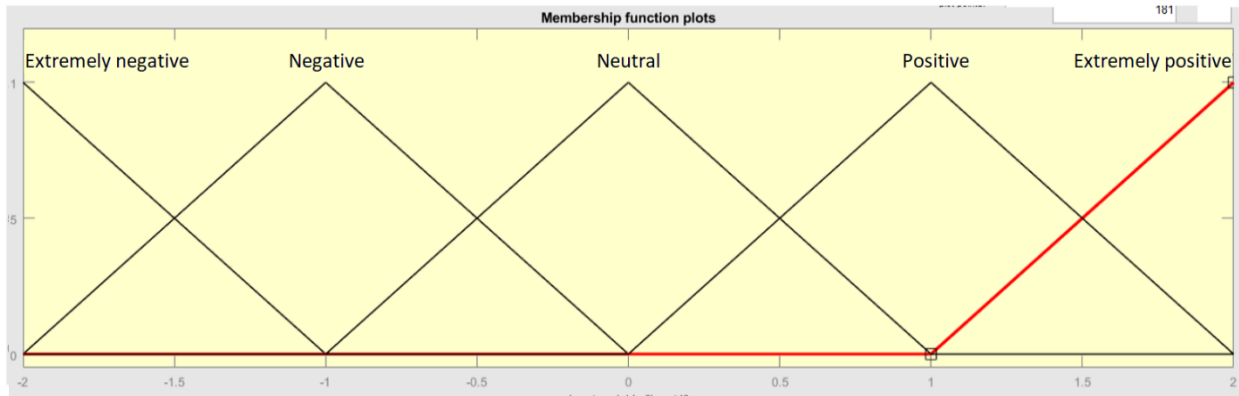


Figure 9. The membership function plot for the expert system based on the risk factor summation method

The adjusted sum of the Risk factor summation method is the sum of all evaluated factors multiplied by 250, as shown on the formula 3. The output of the method is the sum of the average company value in the industry and the adjusted sum. However, based on the assumption the output of the method will not be calculated and the risk value will be defined based on the value of the adjusted sum.

$$AS_{RFS} = \sum_{i=1}^{12} (250 * x_i) \quad (3)$$

where x_i is the numerical representation of each evaluated factor.

An example of the risk factor summation method calculations is shown in table 12.

Table 12. The example of the risk factor summation method

Input		Output
The factor	Evaluation value	
Risk of the Management	1	1100
Stage of the business	2	
Political risk	-1,2	
Supply chain or manufacturing risk	-2	
Sales and marketing risk	0	
Capital raising risk	0	
Competition risk	1,3	
Risk of Technology	1,8	
Risk of Litigation	1,5	
International risk	-0,9	
Risk of Reputation	-0,1	
Exit value risk	1	

IV.3.3 Risk value determination

According to the possible values of the factor evaluation, the possible output values for the Risk factor summation method are in the range $[-2, 2]$.

The output of the expert system based on the Risk factor summation method is the risk level, which has three possible values: low risk, medium risk and high risk. It is decided to divide the output value of the Risk factor summation method into 3 equal ranges and assign each range to one of the possible risk levels, as shown on figure 10.



Figure 10. The risk values for the Risk factor summation method

IV.3.4 Rules determination:

Based on formula 2 in the case of the risk factor summation method, the number of rules equals to

$$244140625 = 5^{12} .$$

The rules are represented in figure 11. Here each term value is replaced by a numeric number for easier representation, $T_i = \{\text{extremely negative, negative, neutral, positive,}$

extremely positive} equals to $T = \{-2, -1, 0, 1, 2\}$. The output of the rules is determined by figure 10.

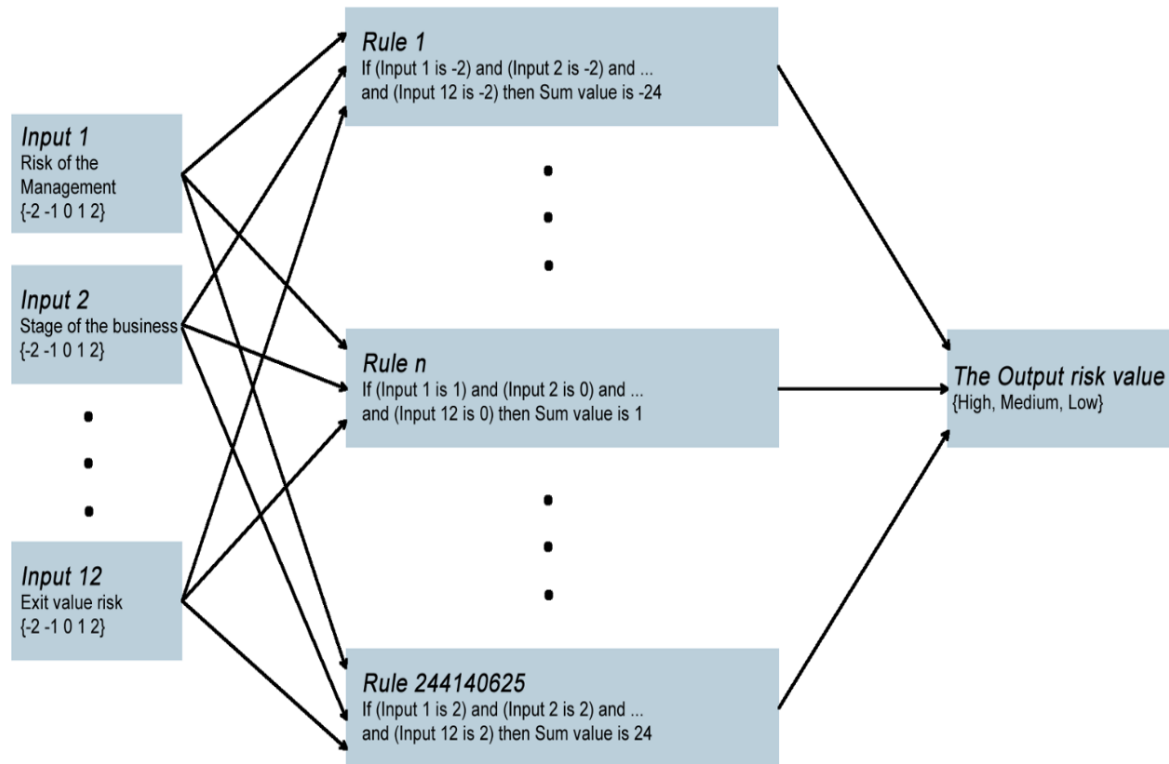


Figure 11. The rules for the Risk factor summation method

IV.4 Expert subsystem based on the scorecard method

The development of the scorecard method-based expert system needs additional preparation. This section contains the necessary data analysis for defining the weights in the scorecard method and the development of the expert subsystem.

IV.4.1 Data collection for the scorecard evaluation method

The data analysis for the method weights definition is crucial for meeting the general requirements and the assumptions made. Based on the general information and the assumptions the data collection is not applicable to the Berkus and Risk factor summation method.

The scorecard method evaluates a startup by seven factors. Each factor for the target company can be estimated by one of the five possible values: much worse than average, worse than average, same as average, better than average and much better than average. A numerical representation is required for each estimation value, which will be utilized in the calculation of the result.

After the evaluation of the factors, the adjustment sum is calculated in this way, as shown by formula 4.

$$AS_{\text{scorecard}} = \sum_{i=1}^7 x_i * w_i \quad (4)$$

where AS - adjustment sum, x_i is the numerical representation of each evaluated factor, w_i is the weight determined for each factor.

The general factor weight ranges are presented in table 13. It should also be taken into account that for one industry and one area, the factor weight is constant.

Table 13. Main factors estimated by the scorecard method

№	The factor	The factor weight
1	Strength of the Management Team	0-30%
2	Size of the Opportunity	0-25%
3	Product/Technology	0-15%
4	Competitive Environment	0-10%
5	Marketing/Sales Channels/Partnerships	0-10%
6	Need for Additional Investment	0 – 5%
7	Other	0 – 5%

To determine the constant value of the factor weights for the IT industry in Europe the following research methods were used:

- Analyze publicly available data sources.
- Analyze online resources such as search engines, social media platforms, and online forums.
- Analyze secondary data such as financial statements, case studies, or other publicly available information.

IV.4.1.1 Data analysis

To determine the appropriate weights for the factors used in the scorecard method, it was crucial to select research studies that specifically analyzed the impact of those factors on the success of IT startups in Europe. Table 14 displays the articles that were selected for this analysis.

Table 14. Articles are chosen for the factor weights determination

№	Title	Geographical area	Literature reference
1	Stakeholders' Perception to Characterize the Start-ups Success	Europe	(Gerhardt et al., 2021)
2	Econometric Estimation of the Factors That Influence Startup Success	Europe (Spain)	(Santamaria & Bulchand-Gidumal, 2021)
3	Success Factors of Startups in the EU—A Comparative Study	Europe	(Skawińska & Zalewski, 2020)
4	Startup Success Factors in the Capital Attraction Stage: Founders' Perspective	Europe (Russia, Latvia)	(Prohorovs, Bistрова, Ten, 2018)
5	Critical Success Factors of a Design Startup Business	Europe	(Kim et al., 2018)

All the research that was selected places significant emphasis on the management team's strengths, management skills, and entrepreneurship abilities. This factor is considered the most important from the perspectives of both investors and entrepreneurs, as stated by (Prohorovs, Bistрова, Ten, 2018). However, (Kim et al., 2018) suggest that the strength of the team should not be overestimated.

The size of the opportunity is also one of the key success factors which are mentioned in all research, but in some articles, it is not included in the top most important ones. This factor is determined as the environmental factor, which cannot be affected (Santamaria & Bulchand-Gidumal, 2021), (Prohorovs, Bistрова, Ten, 2018) (Skawińska & Zalewski, 2020).

The product/technology innovation factor is estimated as more valuable compared to management skills (Kim et al., 2018). Meanwhile, entrepreneurs and investors also highly value the characteristics and features of a product (Prohorovs, Bistрова, Ten, 2018). Based on the information from (Gerhardt et al., 2021) the technology factor is in third place after the team and the environmental uncertainties. (Santamaria & Bulchand-Gidumal, 2021) is mostly concentrated on other success factors and product/technology is not considered.

The competitive environment factor is not mentioned in the research as a separate factor. Mostly it is included in the same group with environmental factors (Gerhardt et al., 2021). As mentioned, (Skawińska & Zalewski, 2020) there is a difference between launching a startup in Eastern or Western Europe. According to the research, the risk level for starting a business in Western Europe is a lower and factors such as competitive environment and Marketing/Sales Channels/Partnerships should have lower value for evaluation if the startup will be launched in Western Europe.

The need for additional investments is not a key success factor for all of the research. And the other factor is only mentioned in (Prohorovs, Bistrova, Ten, 2018), as one of the success-affecting factors.

The following table 15 shows the result of the research analysis. Here the factors are marked as “+++” is mentioned and has a big impact on successes, “++” is mentioned and has an impact on successes, “+” is not mentioned or has no impact on successes.

Table 15. The factor weights evaluation summary

The factors	Research articles					The factor weight	
	1	2	3	4	5	Eastern Europe	Western Europe
Strength of the Management Team	+++	+++	+++	+++	++	28%	
Size of the Opportunity	+++	+++	+	+++	+++	22%	
Product/Technology	+++	+	+	+++	+++	11%	
Competitive Environment	+	+	++	+++	+++	7%	5%
Marketing/Sales Channels/Partnerships	+++	+++	++	++	+++	9%	7%
Need for Additional Investment	+	++	+	+	+	2%	
Other	+	+	++	+++	+	3%	

IV.4.2 Expert subsystem development

The scorecard method has seven evaluation factors, each of which can be evaluated on a scale between 0 and 200. So, for each factor, the fuzzy set is defined on $X_i = [0, 200]$. All parameters should be evaluated impartially and objectively. The set of possible verbal meanings for all factors is the same and is determined as $T_k = \{\text{much worse than average, worse than average, same as average, better than average, much better than average}\}$.

IV.4.2.1 Fuzzy variables

As mentioned in the assumptions, the fuzzy variables for the current subsystem are equal to the risk factors defined in the scorecard method. The fuzzy variables are the following:

- 1) Strength of the Management Team. Is the team complete? Experienced? Coachable? How would you evaluate this parameter compared to other companies?
- 2) Size of the Opportunity. Is the target market quantifiable? How would you evaluate this parameter compared to other companies?

- 3) Product/Technology. Does the company have compatible products or technology? How would you evaluate this parameter compared to other companies?
- 4) Competitive Environment. Does the company have any barriers to entry? How would you evaluate this parameter compared to other companies?
- 5) Marketing/Sales Channels/Partnerships. Does the company have well-defined sales and marketing strategy, sales channels or partners? How would you evaluate this parameter compared to other companies?
- 6) Need for Additional Investment. Does the company need additional investment? How would you evaluate this parameter compared to other companies?
- 7) Other. Does the company have any other specific needs, which are not mentioned before? How would you evaluate this parameter compared to other companies?

The scorecard method-based expert system comprises seven input variables and one output variable that estimates the risk value. The risk value is computed using the adjusted sum, which is based on different weights for each factor and depends on the region, as discussed in chapter IV.3. Due to this dependency, only a general expert system can be developed for this method. Therefore, the adjusted sum will be calculated separately, and the expert system will map the input values to general risks.

IV.4.2.2 Definition of membership functions of fuzzy sets.

The membership functions for each fuzzy set have the triangle value, functions are defined in the following way:

Much worse than average $\lambda_i(x) > 0, \lambda_{mw}(x) = trimf[-50 \ 0 \ 50]$

Worse than average $\lambda_i(x) > 0, \lambda_w(x) = trimf[0 \ 50 \ 100]$

Same as average $\lambda_i(x) > 0, \lambda_a(x) = trimf[50 \ 100 \ 150]$

Better than average $\lambda_i(x) > 0, \lambda_b(x) = trimf[100 \ 150 \ 200]$

Much better than average $\lambda_i(x) > 0, \lambda_{mb}(x) = trimf[150 \ 200 \ 250]$

The plot of the membership functions is shown in figure 12, the fuzzy set is defined on $X_i = [0, 200]$ and the term is following $T_k = \{\text{much worse than average, worse than average, same as average, better than average, much better than average}\}$.

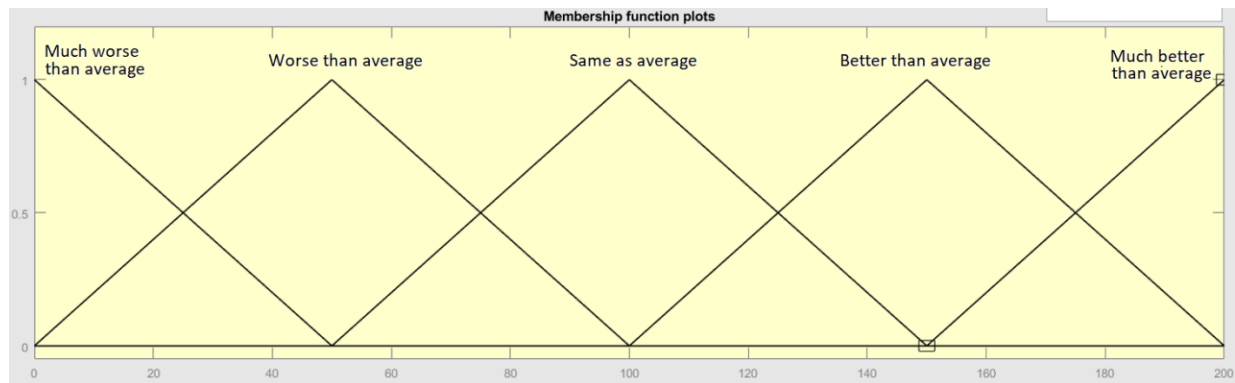


Figure 12. The membership function plot for the expert system based on the scorecard method

The scorecard method calculates the adjusted sum as the sum of all evaluated factors multiplied by their respective weights, as shown by formula 4. The output of the method is the sum of the average company value in the industry and the adjusted sum. However, based on the assumption, the output of the method will not be calculated, and the risk value will be determined based on the adjusted sum value. The output also varies by region, which leads to two possible calculation methods. Weights for each factor are presented in table 15, chapter IV.4.1. Table 16 provides an example of how the calculation is performed.

Table 16. The example of the scorecard method

Input		Output	
The factor	Evaluation value	Value for Eastern Europe	Value for Western Europe
Strength of the Management Team	12	3,36	
Size of the Opportunity	57	12,54	
Product/Technology	200	22	
Competitive Environment	100	70	50
Marketing/Sales Channels/Partnerships	0	0	0
Need for Additional Investment	175	3,5	
Other	25	0,75	
Total value:		112,15	92,15

IV.4.2.3 Risk value determination

According to the possible values of the factor evaluation, there are two possible output values for the scorecard method, for two possible regions. The range for Western Europe is [0, 156], while the range for Eastern Europe is [0, 164].

The output of the expert system based on the scorecard method is the risk level, which has three possible values: low risk, medium risk and high risk. It is decided to divide the output value of the scorecard method into 3 equal ranges and assign each range to one of the possible risk levels, as shown in figures 12-13.



Figure 13. The risk values for the scorecard method for Western Europe



Figure 14. The risk values for the scorecard method for Eastern Europe

IV.4.2.4 Rules determination

In the case of the scorecard method the number of rules does not depend on the area, the number of rules equals to

$$78125 = 5^7 .$$

The rules are represented in figure 15. Here each term value is replaced by a numeric number for the easier representation, $T_i = \{\text{much worse than average, worse than average, same as average, better than average, much better than average}\}$ equals to $T = \{0, 50, 100, 150, 200\}$. The output of the rules is determined by figures 13-14.

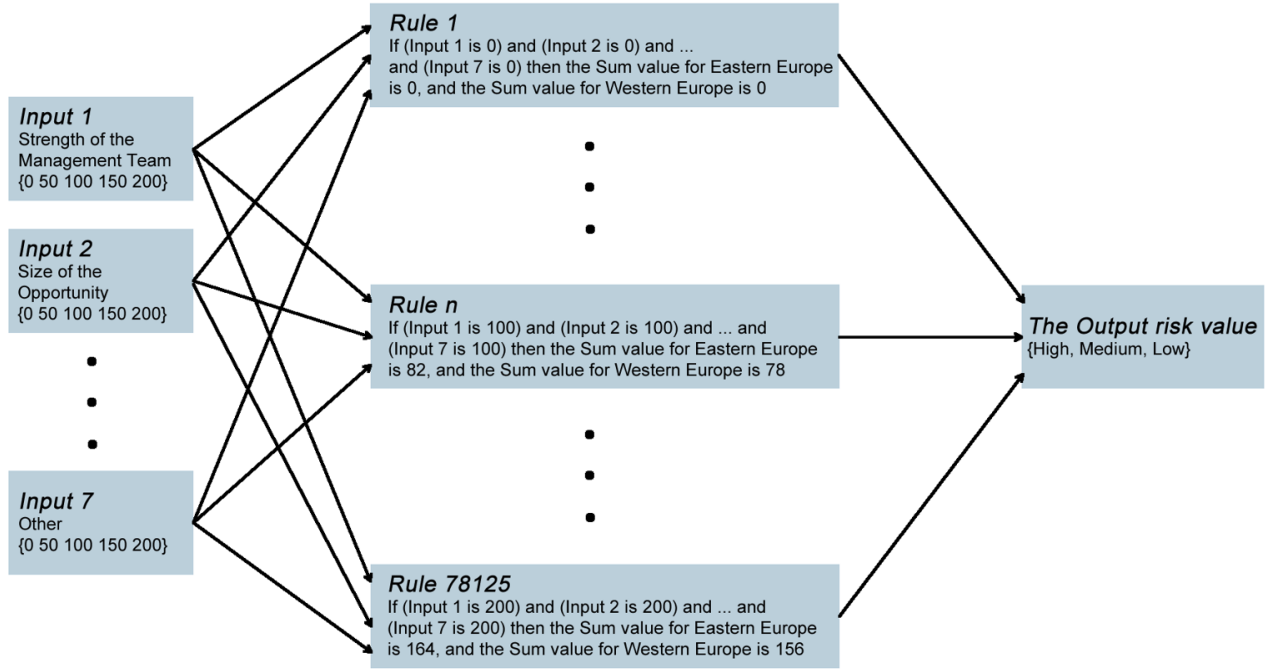


Figure 15. The rules for the scorecard method

IV.4.3 Calculation of the general output of the expert system

Three distinct expert subsystems are developed in the fuzzy tool in Matlab. However, the purpose of the project is not to execute three separate methods for evaluating startups, but to design a cohesive expert system. While the three methods yield individual risk values, they do not provide an overall assessment. Therefore, to achieve the objective of the thesis, a specific calculation logic must be employed to determine the general assessed risk.

Each pre-money valuation method that has been selected is considered equally significant and utilized. As a result, a decision has been made to compute the overall result of the system by taking the average of the existing outputs.

Executing the step is relatively straightforward since it involves computing the average of all risk values acquired, as demonstrated in the formula 5.

$$Risk_{general} = \frac{RV_{Berkus} + RV_{RFS} + RV_{sc}}{3} \quad (5)$$

where the RV_{Berkus} is the output of the Berkus expert system, RV_{RFC} is the output of the risk factor summation expert system, RV_{sc} is the output of the Scorecard expert system.

IV.5 Development of the expert system as a web application

The Berkus, risk factor summation, and scorecard methods were implemented utilizing fuzzy tools in Matlab, resulting in three distinct subsystems, each providing a startup risk value. However, the subsystems could not be integrated, leading to the inability to obtain a

comprehensive output. Additionally, due to the excessive number of factors and rules, the system's operation was slow. To enhance the system's performance by incorporating a graphical interface, accelerating calculations, and integrating all subsystems into one expert system, it was decided to develop a web application for the expert system. This part of the 4th chapter provides web application expert system development.

The general logic of the application is like the previous implementation:

- 1) The user chooses which method or combination of methods should be used for the risk evaluation.
- 2) The user estimates each factor, based on the chosen method, within the provided values.
- 3) Based on the estimated factors, the system calculates the risk value of the chosen method.
- 4) Steps 2-3 are repeated till the risk value of all chosen method are not calculated
- 5) The output, all calculated risk values and the general risk value is provided for the user.

IV.5.1 Implementation of the fuzzy logic

Since the fuzzy tool solely exists in Matlab and must be utilized in the web application expert system, development commenced by creating the “fuzzy logic implementation” for each of the methods.

The first step is to map the input values with the corresponding probability and the value of the fuzzy set defined by the membership function.

Each method has a matrix of predefined values of the ranges of fuzzy sets, the values of the membership functions and the probabilities.

Mapping happens by comparing the input value with the corresponding row of the matrix and buffering the related value of the probability and the membership function.

In case the probability is less than 1 and the membership function cannot be clearly defined, then two possible probabilities and values of membership functions are buffered. Such logic is possible only in case all membership functions are symmetric. Mapping is done consistently for each input value.

The input of this step is the estimated value of the factor, the output is probabilities and the value of the fuzzy set.

Example 1

For instance, the value can be estimated in the range between 1 and 2. So, the fuzzy set is defined on $X_i = [1, 2]$ with step 0.1. The set of possible verbal meanings is determined as $T = \{\text{small, big}\}$.

The membership functions are defined in the following way and the plot of the membership functions is represented in figure 16.

Small $\lambda_i(x) > 0, \lambda_m(x) = \text{trimf}[0\ 1\ 2]$

Big $\lambda_i(x) > 0, \lambda_b(x) = \text{trimf}[1\ 2\ 3]$

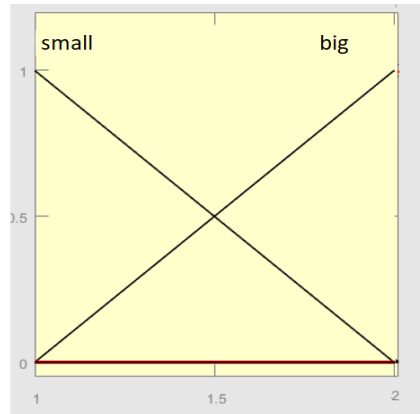


Figure 16. The demo membership function plot

For such a case the matrix of the predefined values will look as shown in table 17.

Table 17. The example of the predefined values matrix

Possible input	1,0	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,0
Probabilities	1,0	0,9	0,8	0,7	0,6	0,5	0,4	0,3	0,2	0,1	1,0
Membership value	small	small	small	small	small	small	small	small	small	small	big

If the input is 1,4 the output of the mapping will be [0,6; small], [0,4; big]. That means that with the 0,6 probability, the value can be small and with the 0,4 probability the value is big.

The second step involves creating a rules matrix that includes every possible combination of fuzzy set values. However, to enhance the performance of the expert system, the web application builds only the active rules matrix. This assumption is possible only in the case of the Berkus, the risk factor summation, and the scorecard methods. This is because of the fact that the rules for the subsystems are based on the sum of the estimated factors as shown in Figures 8, 11, and 15. So, the input of the step is the probabilities and the value of the fuzzy set, and the output of the step is the matrix of all possible combinations of values obtained in the previous step.

Example 2

Let's assume that the definition of the fuzzy sets and the membership functions are the same as in example 1. However, there are 3 input values now. The input values are following:

Value 1 = 1,4

Value 2 = 1,8

Value 3 = 2

After the first step execution, the mapping values are the following:

Value 1

Value 2

Value 3

[0,6; small]

[0,2; small]

[1; big]

[0,4; big]

[0,8; big]

The result of the second step is shown in table 18.

Table 18. The example of the activated rules matrix

№	Value 1	Value 2	Value 3	Output value
1	small	small	big	
2	big	small	big	
3	small	big	big	
4	big	big	big	

The third step is to define the output value based on the active rules' matrix obtained in the second step. This is possible for Berkus, the risk factor summation and the scorecard methods, as activated rules have a strong correlation with the estimated factors. During this step values on each row of the activated rules matrix are summed and the sum on each row is compared to the values defined on figures 7, 10, 13 or 14. As a result, the “Output value” column is a field with values. The output risk value of each subsystem is the average value of the “Output value” column.

Example 3

Let's assume that the definition of the fuzzy sets and the membership functions are the same as in example 1 and the results of the second step are given in example 2. The rule is as follows: if more than 2 values are small, the output is small and if more than 2 values are big, the output is big. The general output has the majority values, as shown in table 19.

Table 19. An example of the output of the system

№	Value 1	Value 2	Value 3	Output value
1	small	small	big	small
2	big	small	big	big
3	small	big	big	big
4	big	big	big	big
The general output				BIG

IV.5.2 User interface development

The calculation logic of the application is described in 4.5.1. The following part provides an overview of the application's general logic and the user interface design. The web app has multiple pages, including the starting page, input pages for the Berkus, Risk factor summation, and Scorecard methods, as well as a result output page.

The starting page contains welcoming information, a short text about the importance of the startup risk evaluation, a description of the expert system and three checkboxes for the Berkus, Risk factor summation, and Scorecard methods. The user can choose the methods which will be used for the risk evaluation. Based on this choice the user is navigated to the input page of the selected method, after pressing the “Continue” button. The starting page is presented in figure 17.

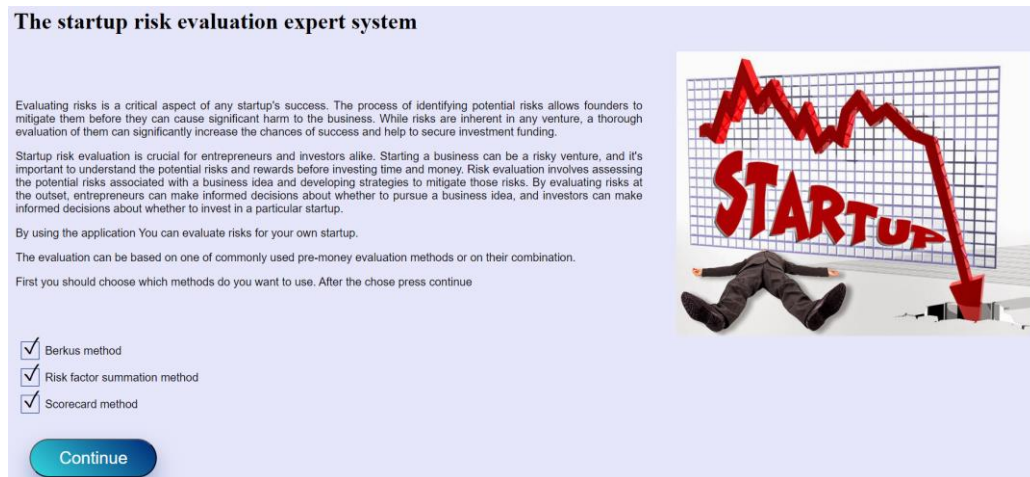


Figure 17. The starting page of the web application

The input page for the Berkus method contains short information about the Berkus method and the instructions for interface usage. The factors can be estimated by values from 0 to 500 by setting the appropriate value by the scrollbar. The input page for the Berkus method is presented in figures 18-19. Scrollbar is chosen as the input element to minimize and protect users' input possibilities. After pressing the “Submit input” button the user is navigated to the output page or the input page of the following method.

THE BERKUS METHOD

The **Berkus Method** is an evaluation technique used to assess the potential of a startup or business idea. Developed by Dave Berkus, a successful entrepreneur and angel investor, this method involves analyzing several critical factors, including the market size, competition, team strength, technology, and financial projections. The Berkus Method assigns a score to each of these factors, which are then combined to provide an overall evaluation of the idea's potential. This evaluation helps investors determine whether to invest in the idea or not, and it also provides valuable feedback to the entrepreneurs to refine their idea and business plan.

The American venture capitalist and angel investor Dave Berkus created the Berkus model as a reaction against the poor track record of startup companies to meet their financial targets. The Berkus Method of evaluation is an early-stage pre-money valuation method that was created to find a starting point without relying upon the founder's financial forecasts. The method quantifies a startup's value by assessing qualitative qualities instead of quantitative ones. Each key factor should be estimated at up to €500 thousands, which allows young startups to reach a value of up to €2.5 million. The essence of the Berkus method is to evaluate the elements of risk reduction in monetary terms.

Benefits of the Berkus Method

- The Berkus method is a straightforward model which is based on qualitative aspects. This is a traditional way to evaluate pre-money startups.
- The method provides a quick rough evaluation.
- The Berkus model is easy modifiable.
- The method considers corporate governance and risk management topics.

The main limitations of the Berkus Method works

- The method is too simplified.
- The method ignores financial risk.

How does the Berkus Method works?

The method has five evaluation factors each of them has to be estimated by the user. Each key factor should be estimated at up to €500 thousands. After each factor is estimated, the general startup value is calculated, startups are able to reach a value of up to €2.5 million. The risk level is calculated based on the value of the startup evaluation. The risk of the startup launching can be Low, Medium or High.

The Factors used in the Berkus Method

Quality of the idea (basic value): Quality of the idea (basic value). Does the company have an exciting business idea? How good would you describe/evaluate your business idea?

Existence of a prototype(technology): Existence of a prototype(technology). Does the company have an exciting technology or a solid product or prototype that attracts customers? How good would you describe/evaluate the product/technology?

Team quality (value of the founding team): Team quality (value of the founding team). Has the company assembled an excellent management team? How good would you describe/evaluate your management team?

Strategic partnerships (successful market entry): Strategic partnerships (successful market entry). Does the company have powerful strategic alliances, partners, or a burgeoning customer base? How would you evaluate the existing strategic partnership?

Introduction and product sales: Introduction and product sales. Does the company have any revenue from sales or any signs of revenue growth and a pathway to profitability? How would you evaluate this parameter?

You should estimate each factor of your startup on the scale from 0 till 500

Figure 18. The input page for the Berkus method, method description.

Each value on the scale should be mapped in the following way.

0	not applicable
100	really bad
200	bad
300	normal
400	good
500	really good

Estimate the factors:

Quality of the idea :

0 100 200 300 400 500

Strategic partnerships :

0 100 200 300 400 500

Team quality :

0 100 200 300 400 500

Introduction and product sales :

0 100 200 300 400 500

Existence of a prototype :

0 100 200 300 400 500

[Submit input](#)

Figure 19. The input page for the Berkus method, input fields.

The input page for the Risk factor summation method contains short information about the method and the instructions for interface usage. The factors can be estimated by values from -2 till 2 by setting the appropriate value by the scrollbar. After pressing the “Submit input” button the user is navigated to the output page or to the input page of the following method. The input page for the Risk factor summation method is presented on figures 20-21.

RISK FACTOR SUMMATION METHOD

The **Risk factor summation Method** is a commonly used approach for evaluating the overall risk of a startup. It involves identifying and assessing various risk factors that are relevant to the particular industry and stage of the startup, such as market competition, product development, financial stability, and team experience. Each risk factor is assigned a numerical score based on its severity, and the scores are then summed to arrive at a total risk score. The lower the score, the greater the overall risk of the startup. This method provides a structured framework for assessing and prioritizing risks, allowing startups to better understand and manage their risk exposure.

Benefits of the Risk factor summation Method

- This method is relatively simple.
- The method considers factors, which are not covered by Berkus and Scorecard methods.
- Investors are more likely to pay a premium when buying equity if the target company belongs to a popular industry. This means that the target startup will be worth more if it falls in the industry and sector.

The main limitations of the Risk factor summation Method works

- The method looks at all the things that could go wrong but does not reflect on things that could go right.
- It is assumed that everything is equally weighted.
- The method relies only on the initial group of startups that you select as the representative benchmark for comparison.
- In case a startup refers to a sector that depicts bad performance, investors will not be interested in the whole sector

How does the Risk factor summation Method works?

The method has twelve evaluation factors each of them has to be estimated by the user.

Each key factor should be estimated at the range from -2 till +2.

After each factor is estimated, the adjustment startup value is calculated in the following way:

Estimation	Risk Rationale	Add to the adjusted sum
-2	Extremely negative	-500
-1	Negative	-250
0	Neutral	0
1	Positive	+250
2	Extremely positive	+500

The risk level is calculated based on the value of the startup evaluation.

The risk of the startup launching can be Low, Medium or High.

Figure 20. The input page for the Risk factor summation method and method description.

Estimate the factors:

Management :

-2 -1 0 1 2

Stage of business :

-2 -1 0 1 2

Political risks :

-2 -1 0 1 2

Supply chain and manufacturing :

-2 -1 0 1 2

Sales and marketing strategy :

-2 -1 0 1 2

Competition risk :

-2 -1 0 1 2

Capital raising risk :

-2 -1 0 1 2

Risk of Technology :

-2 -1 0 1 2

Risk of Litigation :

-2 -1 0 1 2

International risk :

-2 -1 0 1 2

Risk of Reputation. :

-2 -1 0 1 2

Exit value risk :

-2 -1 0 1 2

Submit input

Figure 21. The input page for the Risk factor summation method, input fields.

The input page for the Scorecard method is like the previous ones. However, here the user can also choose the region of the startup location. The factors can be estimated by values from 0 to 200 by setting the appropriate value by the scrollbar. After pressing the “Submit input” button the user is navigated to the output page. The input page for the Scorecard method is presented in figures 22-23.

THE SCORECARD METHOD

The **Scorecard Method** is a popular approach for evaluating the risk of a startup. It involves assigning scores to various factors that are deemed important for the success of a startup, such as the experience and expertise of the management team, the size of the target market, the level of competition, the uniqueness of the product or service, and the financial projections. Each factor is assigned a score based on its importance and the startup's performance in that area. The scores are then weighted based on their relative importance and summed to arrive at a total score, which is used to assess the overall risk of the startup. This method allows for a more nuanced evaluation of a startup's risk profile and helps identify areas where the startup can improve to reduce its risk exposure.

In this method, the target startup which is looking for investments is compared with other similar funded startups. The scorecard valuation model compares these companies based on several factors like the stage of development, business sector, and geographic location.

How does the Scorecard Method works?

The method has seven evaluation factors each of them has to be estimated by the user. Each key factor should be estimated comparing the current startup with other companies in the industry and the region. After each factor is estimated, the general startup value is calculated, based on the set weights depending on the industry and the location. The risk level is calculated based on the value of the startup evaluation. The risk of the startup launching can be Low, Medium or High.

The Factors used in the Scorecard Method

Strength of the Management Team: Is the team complete? Experienced? Coachable? How would you evaluate this parameter comparing to other companies?
Size of the Opportunity: Is the target market quantifiable? How would you evaluate this parameter comparing to other companies?
Product/Technology: Does the company have compatible product or technology? How would you evaluate this parameter comparing to other companies?
Competitive Environment: Does the company have any barriers to entry? How would you evaluate this parameter comparing to other companies?
Marketing/Sales Channels/Partnerships: Does company have well defined sales and marketing strategy, sales channels or partners? How would you evaluate this parameter comparing to other companies?
Need for Additional Investment: Does the company have a need in additional investment? How would you evaluate this parameter comparing to other companies?
Other: Does the company have any other specific needs, which are not mentioned before? How would you evaluate this parameter comparing to other companies?

You should estimate each factor of your startup on the scale from 0 till 200

Each value on the scale should be mapped in the following way.

0	Much worse than average
50	Worse than average
100	Same as average
150	Better than average
200	Much better than average

Figure 22. The input page for the Scorecard method, method description.

Estimate the factors and choose the region of your startup

Strength of the Management Team :

0

50

100

150

200

Size of the Opportunity :

0

50

100

150

200

Product/Technology :

0

50

100

150

200

Competitive Environment :

0

50

100

150

200

Marketing/Sales Channels/Partnerships: :

0

50

100

150

200

Need for Additional Investment :

0

50

100

150

200

Others :

0

50

100

150

200

Chose the region

☐ Eastern Europe
 ☒ Western Europe

Submit input

Figure 23. The input page for the Scorecard method, input fields.

The output page contains the general risk value, evaluated by the system and specification for each chosen method. The page contains several bar charts which graphically present the output data. The content of the output page is presented in figures 24-27.

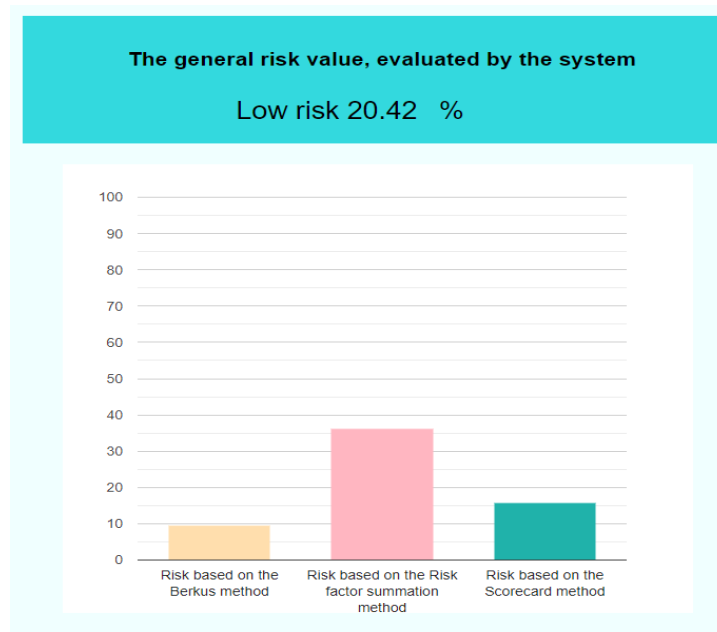


Figure 24. The output page of the expert system

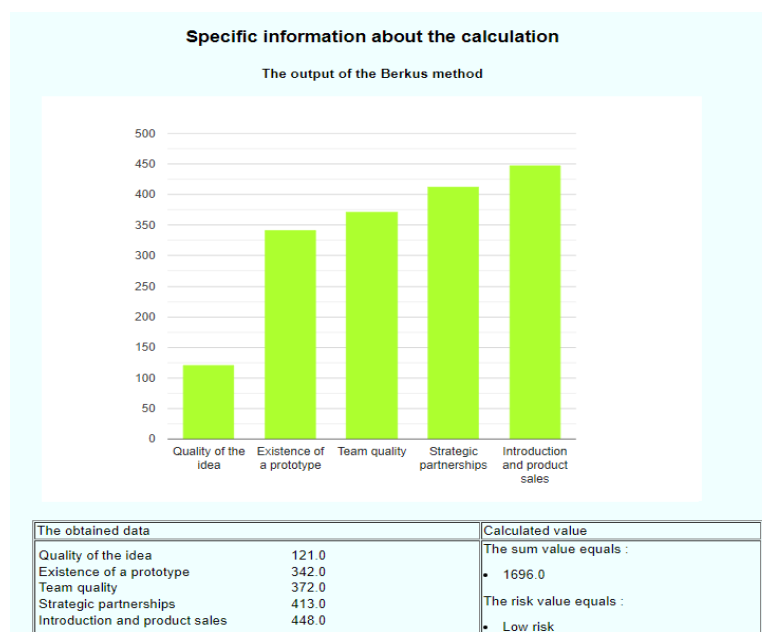


Figure 25. The output page of the expert system, specific information about the calculation.
The output of the Berkus method

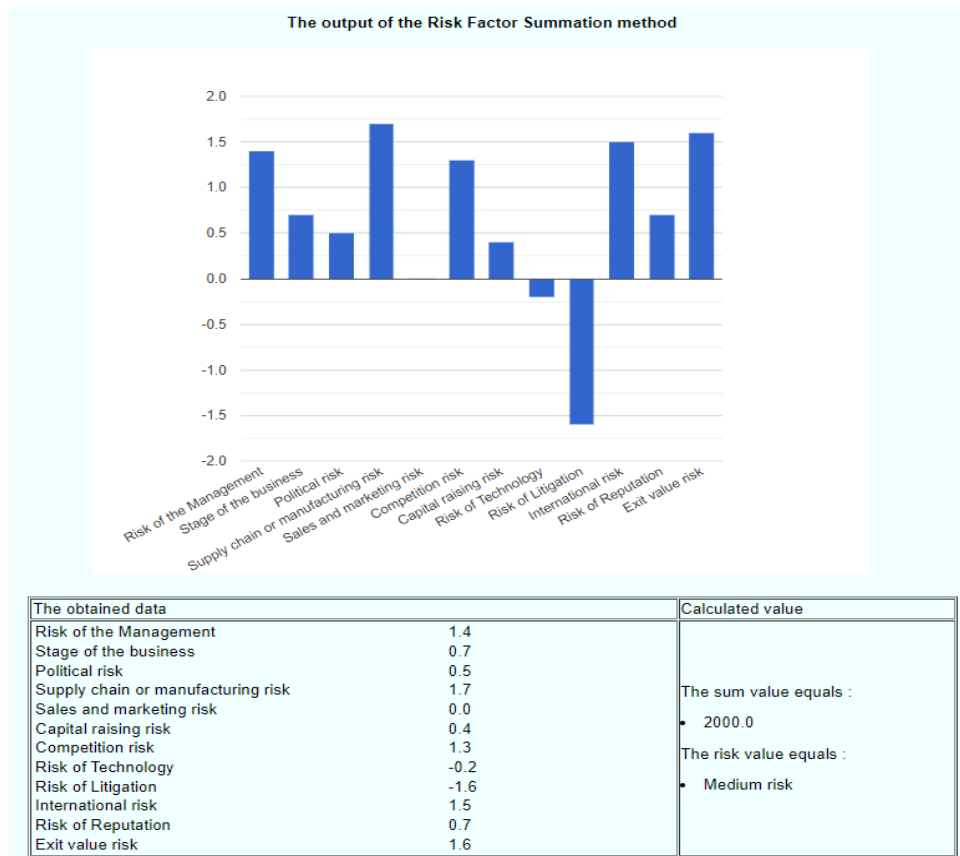


Figure 26. The output page of the expert system, specific information about the calculation.
The output of the Risk factor summation method

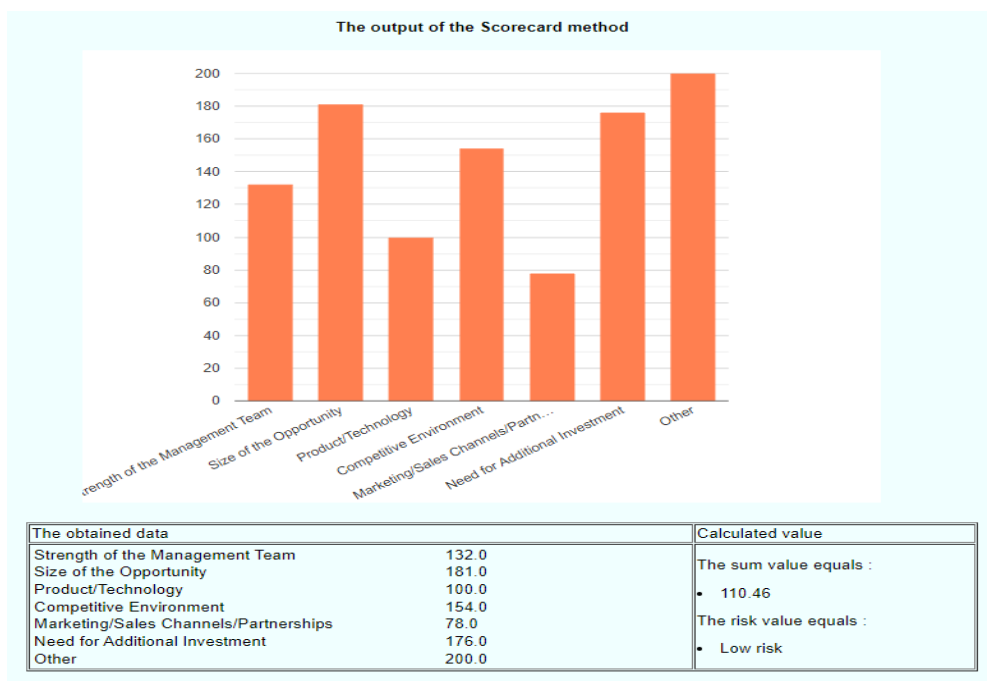


Figure 27. The output page of the expert system, specific information about the calculation.
The output of the Scorecard method

IV.6 Validation of the developed systems

The validation of the expert system is the essential step of the development process. To prove the quality of the developed system following validation techniques are chosen: Precision, Specificity, Sensitivity, Accuracy analyses; User evaluation; Criteria of invited experts.

The whole validation process consists of several steps:

First the Precision, Specificity, Sensitivity and Accuracy analyses of each developed expert subsystem and validation of the whole expert system. Several test data with various inputs and expected outputs are prepared for validation.

Second, the comparison of developed expert systems for startup risk evaluation with existing ones. At the current, stage the developed expert system should be compared with similar existing systems.

Third, the validation of the user interface of the developed web application-based expert system. This stage consists in demonstrating the demo version of the developed application to various users and obtaining an assessment of the clarity and convenience of the user interface.

IV.6.1 Precision, Specificity, Sensitivity and Accuracy analyses of the system

The test data, prepared for validation, has various combinations of input parameters. The expected output, risk value, is defined for each method and shown in figures 7, 10, 13, 14. The expected output for the general system is the average value of risks obtained from each subsystem. The following parameters are calculated. The confusion matrices and the calculation of the parameters are shown in tables 20-24 and the test datasets, used for the validation are presented in the Appendix.

Accuracy — Ratio of correct predictions to total predictions.

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + FN + TN}$$

Sensitivity — Ratio of true positives to actual positives in the data.

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

Precision — Ratio of true positives to total predicted positives

$$\text{Precision} = \frac{TP}{TP + FP}$$

Specificity — Ratio of true negatives to total negatives in the data.

$$\text{Specificity} = \frac{TN}{TN + FP}$$

F1-Score — Considers both precision and recall. It's the harmonic mean of precision and recall.

$$\text{F1 Score} = 2 * \frac{\text{Sensitivity} * \text{Precision}}{\text{Sensitivity} + \text{Precision}}$$

Table 20. Confusion matrix for the Berkus method

		Expected results	
		No	Yes
Actual result	No	True negative: 0	False positive: 0
	Yes	False negative: 0	True positive: 20

Table 21. Confusion matrix for the risk factor summation method

		Expected results	
		No	Yes
Actual result	No	True negative: 0	False positive: 0
	Yes	False negative: 0	True positive: 20

Table 22. Confusion matrix for the scorecard method

		Expected results	
		No	Yes
Actual result	No	True negative: 0	False positive: 0
	Yes	False negative: 0	True positive: 20

Table 23. Confusion matrix for the general expert system

		Expected results	
		No	Yes
Actual result	No	True negative: 0	False positive: 0
	Yes	False negative: 0	True positive: 20

Table 24. The validation results for the general expert system

	Berkus method-based expert subsystem	Risk factor summation method-based expert subsystem	Scorecard method-based expert subsystem	Integrated expert system
Accuracy	1	1	1	1
Sensitivity	1	1	1	1
Precision	1	1	1	1
Specificity	-	-	-	-
F1 Score	1	1	1	1

IV.6.2 Comparison of the developed expert system with existing ones

Currently, it is possible to find many risk management software (Startup Stash), however, these tools could not be used for a startup launching risk evaluation. The risk

estimation is carried out by calculators, which are based on one of the evaluation methods described in chapter II. The calculation tools are based on one method and do not provide the risk value for the startup launching.

The tool which has the closest functionality to the developed expert system is presented by Eqvista (Startup Valuation Software)¹. The Startup Valuation software by Eqvista is a questionnaire with multiple choice questions, where based on given answers the user gets a startup risk assessment report. The comparison results are shown in table 25.

Table 25. Comparison of the two systems

Parameter for comparison	Eqvista Startup valuation software	Developed expert startup risk evaluation system
Used methodologies	Berkus, Risk factor summation, Scorecard, Venture Capital	Berkus, Risk factor summation, Scorecard
Possibility to choose the evaluation method	The user cannot choose which method should be used for the evaluation	The user can choose which evaluation methods to choose
Is the system industry or region specific	No, the evaluation is done based on the theoretical methods description	The evaluation is done for the IT industry for the European region the output depends on the region of the company's operation
Clear UI	+	+
Type of data input	Usage of questioner	Self-estimation of factor values
The report based on the evaluation process	Startup valuation report in PDF format	A report presented on the webpage
Computational speed	fast	fast
Price	89\$	free

In comparison with the Eqvista system, the developed expert risk evaluation system has its advantages and disadvantages. The current expert system has fewer evaluation methods. However, it is not a crucial disadvantage, as the combination of the three selected methods covers many success-related factors.

The expert system is more customizable as the user can choose which methodology should be used for the evaluation.

Both systems provide reports because of the startup evaluation, but the report format is different. The report, provided by Eqvista, is fuller and more complex, but the creation of the

¹ Eqvista Startup Valuation Software: <https://eqvista.com/services/startup-valuation/>

complex report is not the objective of the work. Unlike the Startup valuation software, the expert system provides both the risk value and estimated value of the startup.

The essential difference is that the developed expert system is suitable only for the IT industry, it also depends on the region. The analysis of success factors carried out before the development made it possible to make the system more specialized, so the risk assessment is more accurate.

Moreover, the expert system is free to use, and it has potential for future development and all the differences and disadvantages can easily be eliminated.

IV.6.3 Validation of the user interface

To validate the convenience and clearance of the user interface several people of different age groups were questioned about the user interface of the application.

User interface usability surveys were conducted throughout the entire application development process. All unsatisfactory comments and suggestions for improvement were taken into account during the development process.

Below is a list of questions that were included in the questionnaire about the user interface:

- Is the user interface clear to you?
- Is the information presented clearly and understandably?
- How easy is it to deal with the user interface without developer hints?
- What would you change in the arrangement of elements on the page?
- How easy is it to enter data into the system?
- Is it possible to quickly find the necessary information among

the presented ones?

- Is the output of the system sufficiently clearly presented?
- What other information would you add or remove?

All necessary adjustments were made to the user interface till the testing group of users became satisfied with the result of the user interface.

As a result of chapter IV, the expert system for the risk evaluation of a startup launching was developed. The expert system is a web application that combines the three expert subsystems based on the Berkus method, the scoring method, and the risk factor summation method. The expert system requires risk factor estimation as the input data and provides the informative dashboard and the risk value of the startup launching as the output. The developed

system has future potential compared to already existing solutions. The next chapter contains the discussion of obtained results.

V. DISCUSSION & CONCLUSION

The current chapter provides a discussion of the results obtained in the process of research and development and a comparison with the research outlined in the literature review. The presented expert system is developed to evaluate the risk of the startup launching. The development is done in a way to overcome the limitations identified in previous research.

V.1 Discussion

Based on the research of Akkaya (2019) the expert system is based on the pre-money valuation methods which allow overcoming the problem of lack of quantitative data for startup companies. Considering the results of several studies like Montani (2020), Rismadhanti and Prasetyo (2020) and Hura (2022). Several remarks were taken into account during the expert system development process. As currently there is no single perfect company evaluation and different methods have many limitations, the best solution to the problem is the combination of evaluation methods that cover as many risk factors as possible. So, the developed expert system is based on three qualitative evaluation methods, which cover many problematic aspects of the startup launching process.

According to the research of Salamzadeh and Kawamorita (2015) and Spoiala (2020) startups operate under high uncertainty at each stage of their existence and to minimize the risk probability and diminution of its impact the risk detection and mitigation should be done as early as possible. The current expert system allows us to estimate the risk value before the startup is launched. However, to date, this is the only covered stage of the startup life cycle.

The developed expert system is based on a fuzzy logic calculation which provides the opportunity to estimate the risk factors of the startup in a qualitative and not in the quantitative way. The approach also allows calculating the risk value based on real data as in the Ibraigheeth and Fadzli (2019) research, but the current system operates with the startup evaluation and not the software projects.

Just like Arias-Aranda and others' (2010) work, the current system is based on a fuzzy rule-based model. However, the rules are strictly set for the three chosen evaluation methods. Since the selected risk evaluation methods are universal, the expert system can be adapted to assess the risk of any startup. Thanks to fuzzy logic, the system can estimate such factors, which are difficult to quantify, for example, the "startup idea". The ability to evaluate invaluable factors provides the developed system with an increased level of accuracy of the result.

V.2 Conclusion

The study aimed to develop a web application-based fuzzy expert system for the risk evaluation of the startup launching. In the course of the work, the fundamental theoretical elements necessary for creating an expert system using fuzzy logic were studied and analyzed. In addition, the methods used to evaluate the risks associated with startups were analyzed. Based on the results of this study, the most appropriate methods of evaluating a startup were identified. By integrating the selected methods of qualitative evaluation, it is possible to obtain a comprehensive assessment, since a wide range of risk factors is taken into account.

The developed expert system based on the Berkus, risk factor summation and the scorecard methods consider the risk factors connected to the management of the company, the financial aspects, the novelty of the startup idea, the geographical location and the industry of the company, marketing and sales aspects and possible the political and legal influence.

Based on the data availability the expert system operates only with startups in the IT industry in the European region. The development of the expert system was carried out in several stages. In the first stage, three expert subsystems were developed with the help of the Matlab fuzzy logic toolbox, each system corresponding to one of the selected evaluation methods. At this stage, the rules for the output of expert subsystems were compiled and verified based on the evaluation methods' theoretical description. In the second stage, the logic of expert subsystems in the Java programming language was developed. The third stage consisted of the development of a web application - a unified expert system that combines subsystems developed earlier. The fourth stage of development is the validation of the developed system and its comparison with existing solutions.

Based on the validation results of the developed expert system the calculation logic provides an accuracy rate equal to 1 and the precision and recall equaled to 100%. Comparison of the expert system to already existing solutions presents that the developed expert system does not contain any significant limitations or drawbacks but has some competitive advantages.

Despite the high results obtained during the comparison of the current system and existing solutions, the developed expert system still has some limitations:

- It is limited to three qualitative methods.
- The accuracy and effectiveness of the expert system depend on the quality and completeness of the data used for evaluation. If the data is incomplete or inaccurate, it may lead to incorrect risk assessments.

- The expert system is developed based on current knowledge and understanding of startup evaluation methods and risk factors, and may not account for future developments and changes in the startup ecosystem.
- The expert system may not account for all possible risk factors that could affect a startup, as it is limited to the defined risk factors used in the evaluation process.

In terms of future research, several potential avenues could be explored to further improve the expert system for risk evaluation for startup launching.

Firstly, additional evaluation methods could be incorporated into the system to enhance its accuracy and comprehensiveness. For example, incorporating quantitative methods such as Discounted Cash Flow or Multiples Valuation could provide a more in-depth analysis of a startup's financial health.

Secondly, the expert system could be expanded to include risk evaluation for startups in industries beyond IT, such as healthcare, finance, or energy. This would require a broader range of evaluation criteria specific to each industry.

Thirdly, the expert system could be integrated with other startup-related tools, such as business plan generators or pitch deck builders, to provide a comprehensive suite of resources for entrepreneurs.

Fourthly, future research could focus on providing more detailed descriptions of the output data generated by the expert system. This could involve developing visualizations or other forms of data presentation that help users better understand the risk assessment results.

Fifthly, new methods for calculating risks could be developed and incorporated into the expert system. This could involve exploring different risk assessment models, such as Bayesian Networks or Monte Carlo Simulation, that may provide more accurate or nuanced risk evaluations.

Sixthly, expanding the scope of the expert system to cover other industries and geographical regions could be an important area of future research. This would involve developing industry-specific evaluation criteria and adjusting the system to account for different regional contexts and startup ecosystems.

Finally, further research could be conducted into the application of machine learning algorithms to the expert system, to improve its predictive capabilities and overall performance.

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VII. ANNEX

Table 26. The test dataset for the Berkus expert subsystem validation

№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Quality of the idea	352	300	500	42	144	305	195	290	79	274	456	116	199	385	448	373	206	394	9	237
Existence of a prototype	74	270	82	211	0	295	165	227	357	11	267	154	308	107	247	252	277	79	74	76
Team quality	60	412	420	318	12	465	365	158	417	185	260	76	192	47	370	345	383	303	89	477
Strategic partnerships	409	208	481	174	336	98	335	48	405	29	180	332	139	255	243	417	212	316	257	260
Introduction and product sales	386	269	414	396	9	256	119	233	447	484	468	42	77	138	145	387	72	246	46	354
Total sum	1281	1459	1897	1141	501	1419	1179	956	1705	983	1631	720	915	932	1453	1774	1150	1338	475	1404
Actual risk	m. risk	m. risk	l. risk	m. risk	h. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	h. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	high risk	m. risk
Expected risk	m. risk	m. risk	l. risk	m. risk	h. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	h. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	high risk	m. risk

Table 27. The test dataset for the risk factor summation expert subsystem validation

№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Risk of the Management	-0,9	-0,8	-1	-0,8	2	-1,3	1,6	1,9	2	1,1	1,8	0,7	-0,7	-0,7	-0,1	-0,2	-1,7	1,1	0,6	-0,2
Stage of the business	0,4	0,6	0,3	-1	-1,6	-1,8	-1,9	1,5	1,5	-1,7	0,8	-2	-2	-1,4	0,1	0,3	-2	0,3	-1,2	0,4
Political risk	0,8	0,1	-1,3	-0,2	0,1	-1,5	-0,5	-0,6	-0,9	-0,8	0,6	-0,5	1	1,5	0,4	-0,3	-1,4	-1	0,5	-1,3
Supply chain or manufacturing risk	-0,9	0,7	1,5	-1,4	1,3	1,1	-0,8	-2	-1,3	-1,6	-1	-1,8	-0,1	-0,1	0,1	-1,1	-1,3	1,7	-0,1	1,8
Sales and marketing risk	-1,6	0,4	-0,4	-0,3	1	0,8	-1,3	-1,6	-1,6	1,5	0,6	-1,2	-0,7	0,3	-1,9	1,8	-0,5	0,7	0	-1,3
Capital raising risk	-0,5	-1,4	-0,1	-1,5	-0,6	-0,1	-1	0,4	-0,8	-1,8	0,4	0	0,6	-1	1,8	-1,5	-1,2	-0,7	0,7	1,5
Competition risk	1,8	1,4	-1,5	1,6	0,8	-1,2	-0,1	1,4	-0,3	-1,4	1	-0,8	0,5	-1,4	0,3	-0,9	0,7	-0,2	-1	1
Risk of Technology	1,8	0,6	-0,1	0,3	0,9	-1,6	1	0,4	-0,1	0,1	0,9	0,7	2	1,1	0,5	-1,8	-1,4	1,1	-0,1	1,4
Risk of Litigation	-1,4	0,1	-1	0,4	1,8	0,6	-1,5	0,7	1,5	1	0,7	-0,6	-0,4	-0,2	-1	-1,4	-1,8	-0,3	1	1,4
International risk	0,4	1,8	-1,2	1,4	1,8	0,8	1,4	-0,1	-1	-1,4	1,7	-0,7	-1,3	0,7	0,8	-2	0,9	1,5	-1,7	0
Risk of Reputation	-1	-1,6	1	0,8	-1,3	0,7	0,5	1,4	-0,4	-1,5	0,5	-1,1	-0,8	1,7	0,9	0,9	-1,6	-1,7	1,4	0,4
Exit value risk	1,1	1,3	-1,5	-1,1	1,5	-1,1	0,8	1,7	-0,8	-1,3	0,5	-0,5	-1	1,2	0,5	1,7	1,8	1,8	0	1
The overall range	0	3,2	-5,3	-1,8	7,7	-4,6	-1,8	5,1	-2,2	-7,8	8,5	-7,8	-2,9	1,7	2,4	-4,5	-9,5	4,3	0,1	6,1
Total sum	0	800	-1325	-450	1925	-1150	-450	1275	-550	-1950	2125	-1950	-725	425	600	-1125	-2375	1075	25	1525
Actual risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	m. risk	m. risk	m. risk	h. risk	m. risk	m. risk	m. risk
Expected risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	l. risk	m. risk	m. risk	m. risk	m. risk	m. risk	h. risk	m. risk	m. risk	m. risk

Table 28. The test dataset for the scorecard expert subsystem validation

№	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Strength of the Management Team	91	111	97	80	115	185	152	61	171	149	143	12	112	91	146	183	66	165	178	196
Size of the Opportunity	145	16	22	86	114	30	25	13	13	138	105	48	173	91	19	0	196	140	133	50
Product/Technology	36	75	169	90	196	51	78	43	18	128	60	187	99	144	123	32	67	110	130	107
Competitive Environment	45	168	149	112	62	115	49	8	21	162	117	181	14	133	184	164	32	100	92	140
Marketing/Sales Channels/Partnerships	68	179	187	114	45	47	145	132	12	174	159	143	124	162	10	112	102	45	167	51
Need for Additional Investment	82	9	96	125	194	115	43	34	109	183	122	82	6	197	15	118	129	99	199	116
Other	64	6	143	170	50	67	135	7	114	124	124	74	75	136	194	77	63	178	4	168
Total sum	74,1	71	84,6	76,9	92,6	80,6	78,3	38	60,8	120,5	98,4	63,9	94,8	93,2	78,4	80,9	84,8	107,4	118,9	99,4
Actual risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	h. risk	m. risk	l. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	l. risk	l. risk	m. risk
Expected risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	h. risk	m. risk	l. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	m. risk	l. risk	l. risk	m. risk