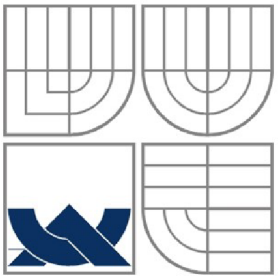

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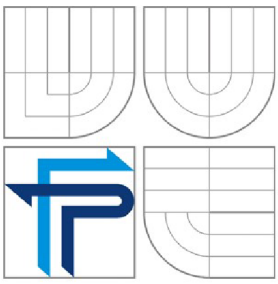
BRNO UNIVERSITY OF TECHNOLOGY



FAKULTA PODNIKATELSKÁ
ÚSTAV EKONOMIKY

FACULTY OF BUSINESS AND MANAGEMENT
INSTITUTE OF ECONOMICS

FUZZY HODNOCENÍ INVESTIC – BROWNFIELD REDEVELOPMENT

FUZZY INVESTMENT DECISION SUPPORT FOR BROWNFIELD REDEVELOPMENT

DISERTAČNÍ PRÁCE
DISSERTATION

AUTOR PRÁCE
AUTHOR

Ing. ZDENĚK BROŽ

VEDOUCÍ PRÁCE
SUPERVISOR

prof. Ing. MIRKO DOHNAL, DrSc.

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Abstract

This dissertation focuses on decision making, investing and brownfield redevelopment. Especially on the analysis, evaluation and selection of previously used real estates suitable for commercial use. The objective of this dissertation is to design a universal method that facilitates the decision making process with many possible alternatives and large number of relevant parameters influencing the decision. The proposed method is based on the use of fuzzy logic, modeling, statistic analysis, cluster analysis, graph theory and sophisticated methods of information collection and processing. New method allows decision makers to process much larger amount of information and evaluate possible investment alternatives efficiently.

Keywords

brownfield, investing, artificial intelligence, fuzzy logic, modeling, cluster analysis, graph theory

Abstrakt

Tato disertační práce se zaměřuje na problematiku investování a podporu rozhodování pomocí moderních metod. Zejména pokud jde o analýzu, hodnocení a výběr tzv. brownfieldů pro jejich redevelopment (revitalizaci). Cílem této práce je navrhnout univerzální metodu, která usnadní rozhodovací proces. Proces rozhodování je v praxi komplikován též velkým počet relevantních parametrů ovlivňujících konečné rozhodnutí. Navržená metoda je založena na využití fuzzy logiky, modelování, statistické analýzy, shlukové analýzy, teorie grafů a na sofistikovaných metodách sběru a zpracování informací. Nová metoda umožňuje zefektivnit proces analýzy a porovnávání alternativních investic a přesněji zpracovat velký objem informací. Ve výsledku tak bude zmenšen počet prvků množiny nejvhodnějších alternativních investic na základě hierarchie parametrů stanovených investorem.

Klíčová slova

brownfield, investování, umělá inteligence, fuzzy logika, model, shluková analýza, teorie grafů

Resumen

Esta disertación se enfoca en el problema de la inversión de bienes raíces y los pequeños a medianos empresarios. Especialmente en el análisis, evaluación y selección de bienes usados con uso comercial. El objetivo de esta disertación es diseñar un conjunto de métodos universales que faciliten el proceso de la toma de decisiones cuando se tienen varias posibles alternativas y un gran numero de parámetros relevantes que influyen sobre la decisión. Los métodos propuestos están basados en la lógica difusa, el modelado, análisis estadístico, análisis de conglomerados, teoría de grafos y una colección de sofisticados métodos de información y procesamiento. Los nuevos métodos permiten a las personas que toman decisiones procesar un mayor numero de información y evaluar de manera eficiente las posibles alternativas de inversión.

Palabras claves

inmobiliario, con una inversión, las PYME, la inteligencia artificial, lógica difusa, el modelado, análisis de conglomerados, la teoría de grafos

Zusammenfassung

Diese Dissertation konzentriert sich auf die Problematik „Immobilieninvestment und KMUs“, insbesondere auf Analyse, Bewertung und Auswahl von bereits bestehenden Immobilien für die gewerbliche Nutzung. Ziel dieser Dissertation ist es, eine Reihe von allgemein gültigen Methoden aufzustellen, die den Entscheidungsprozess mit vielen möglichen Alternativen und eine Vielzahl von relevanten Parametern beeinflussen und somit die Entscheidung selbst erleichtern. Die vorgeschlagenen Methoden basieren auf dem Einsatz von Fuzzy-Logik, Modellerstellung, statistische Analyse, Clusteranalyse, Graphentheorie und ausgefeilten Methoden zur Datenerhebung und-verarbeitung. Neue Methoden ermöglichen es Entscheidungsträgern, viel größere Mengen an Informationen zu verarbeiten und mögliche Anlagealternativen effizienter zu bewerten.

Stichworte

Immobilien, Investitionen, KMU, künstliche Intelligenz, Fuzzy-Logik, Modellerstellung, Clusteranalyse, Graphentheorie

Sommario

Questa tesi si concentra sulla problematica degli investimenti immobiliari e delle piccole e medie imprese. In particolare sull'analisi, la valutazione e la selezione di immobili precedentemente già utilizzati per uso commerciale. L'obiettivo di questa tesi è il raggruppamento di metodi universalmente validi che facilitino il processo decisionale con molte possibili alternative e un gran numero di parametri che influenzino la decisione. I metodi proposti sono basati sull'uso della logica fuzzy, creazione di modelli, analisi statistica, analisi cluster, teoria dei grafi e sofisticati metodi di raccolta e trattamento delle informazioni. Con questi nuovi metodi chi ha il potere decisionale ha a disposizione una quantità molto più ampia di informazioni e quindi sarà possibile valutare in maniera molto più efficiente le alternative di investimento.

Parole chiavi

immobili, investimenti, PMI, intelligenza artificiale, logica fuzzy, modellazione, analisi cluster, teoria dei grafi

抽象的な

本論文は、中小企業への不動産投資、小さな問題に焦点を当て。特に分析、評価、以前に使用した不動産の選択、商業用に最適です。本論文の目的は、意思決定の多くの選択肢と関連するパラメータの決定に影響を及ぼす多数のプロセス作りを容易に普遍的なメソッドのセットを設計することです。提案手法は、ファジーロジックの使用に基づいて、モデリング、統計解析、クラスタ分析、グラフ理論、情報の収集と処理の洗練された方法。新しいメソッドは、意思決定者が情報のはるかに大きい量を処理できるように、効率的な投資の選択肢を評価する。

キーワード

不動産、投資、中小企業、人工知能、ファジー論理、モデリング、クラスター分析、グラフ理論

Аннотация

Диссертация посвящена проблеме реального инвестирования недвижимости у малых и средних предприятий. Данная работа направлена, прежде всего, на анализ, оценку и выбор ранее использовавшейся недвижимости, подходящей для коммерческого использования. Цель данной диссертационной работы состоит в разработке комплекса универсальных методов, которые облегчают процесс принятия решения с несколькими возможными альтернативами и на основе большого количества соответствующих параметров, влияющих на принятие решения. Предложенные методы основаны на использовании нечеткой логики, моделирования, статистического анализа, кластерного анализа, теории графов и современных методов сбора и обработки информации. Новые методы позволяют лицам, принимающим решения, обрабатывать гораздо больший объем информации и эффективно оценивать возможные альтернативные варианты инвестирования.

Ключевые слова

Недвижимость, инвестиции, малые и средние предприятия, искусственный интеллект, нечеткая логика, моделирование, кластерный анализ, теория графов

摘要

本论文的重点是中小企业的房地产投资问题，特别是对那些先前投入使用的商用房地产进行分析，评估和选择。本论文旨在设计一套从众多可能的选择和大量相关的数据中做出决策的通用方法。提议的这些方法 是基于使用模糊逻辑，模型，统计分析，聚类分析，图论以及收集和处理信息的复杂方法。新方法使决策者们能够处理更多的信息并有效地评估可能的投资选择。

关键词

房地产，投资，中小企业，人工智能，模糊逻辑，模型，聚类分析，图论

Résumé

Cette thèse se concentre sur les problèmes d'investissement de biens immobilier a destination des petites et moyennes entreprises (PME). Elle se focalise surtout sur les analyses, l'évaluation et la sélection de biens immobiliers usager adaptés à un usage commercial. L'objectif de cette thèse est de concevoir un ensemble de méthodes universelles qui faciliteront le processus décisionnel. Un certain nombre d'alternatives et un nombre important de paramètres influençant le processus décisionnel. Les méthodes proposées se baseront sur l'utilisation de la logique floue, de l'analyse statistique de modèles, de l'analyse par grappes, de la théorie des graphes et de méthodes sophistiquées pour la collecte et le traitement d'informations. De nouvelles méthodes permettent aux décideurs de traiter une quantité d'information nettement plus importante que les solutions existantes, et ainsi d'évaluer les opportunités d'investissement de manière plus affinée et efficace.

Mots-clés

Immobilier, investissement, PME, intelligence artificielle, logique floue, modélisation, analyse par grappes, théorie des graphes

Citing this dissertation

ČSN ISO 690 a ISO 690-2

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BROŽ, Z. *Fuzzy investment decision support for brownfield redevelopment.* Dissertation. Brno : Brno university of technology, Faculty of business and management, 2012. 149 p. PhD advisor Prof. Ing. Mirko Dohnal, DrSc.

APA general format

Brož, Z. (2012). Fuzzy investment decision support for brownfield redevelopment. (Doctoral dissertation, Brno university of technology, Faculty of business and management, 2012).

MLA general format

Brož, Z. Fuzzy investment decision support for brownfield redevelopment. Diss. Brno university of technology, Faculty of business and management, 2012.

Turabian general format

Brož, Z. "Fuzzy investment decision support for brownfield redevelopment." Ph.D. diss., Brno University of Technology, Faculty of Business and Management, 2012.

Prohlášení

Prohlašuji, že disertační práci na téma „Fuzzy hodnocení investic – brownfield redevelopment“ jsem vypracoval samostatně pod vedením vedoucího disertační práce prof. Ing. Mirko Dohnala, DrSc. a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny náležitě citovány v práci a uvedené v seznamu literatury na konci práce. Jako autor uvedené disertační práce dále prohlašuji, že v souvislosti s vytvořením této disertační práce jsem neporušil autorská práva (ve smyslu zákona č. 121/2000 Sb. O právu autorském a o právech souvisejících s právem autorským).

V Brně dne 18. 12. 2012

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Ing. Zdeněk Brož

Poděkování

Tímto především děkuji vedoucímu disertační práce prof. Ing. Mirku Dohnalovi, DrSc. za odborné vedení práce, poskytnutí programového vybavení, užitečných rad a připomínek, které přispěly k vypracování této práce. Dále děkuji prof. Ing. Petru Dostálovi, CSc. za cenné rady, doporučení. Též děkuji rodině, přátelům a kolegům za morální podporu a motivaci k dokončení této práce.

Contents

Introduction

This research focuses on several areas including investing, decision making and brownfield redevelopment. Decision makers often have a very difficult task because they have to analyze large amount of information and they have a very limited time to make the decision. Long-term investments like for example the purchase of new building complex or a brownfield site have strategic importance. These investments require a significant amount of resources and incorrect decision are costly.

As the amount of available information is steadily increasing there is a need to develop new sophisticated methods that facilitate the process or data collection, analysis and evaluation. There is a significant difference between different fields of science. For example mathematics and physics have precise variables and relations. Social sciences like for example economics have also variables and relations but it is more difficult to measure and evaluate these variables. Physics has general laws and rules that are constant and valid at all times. Economics also has laws but the market environment is constantly changing. It is more difficult to make predictions about the future markets than it is to predict the behavior of a system which follows the precise rules of physics. Fuzzy logic allows researchers to work with imprecise or even unknown variables that can frequently be found in economics or in investment decisions.

This dissertation discusses the use of fuzzy logic and modeling and its application in investing. This research focuses on the application of fuzzy logic as a decision making support for investors who plan to redevelop a brownfield site. Due to a high degree of complexity of this decision making problem - the goal of this research is to design a complex method that facilitates the use of fuzzy logic in economics and especially in the field of real estate investment and in the process of investment evaluation of brownfield sites.

1 Research objectives

This chapter discusses the individual research objectives. Due to the complex nature of the decision making process about long-term investments it is necessary to reach several objectives at once. All these objectives are important in different phases of the research. This research is conducted with the intention to create a reliable method that can be applied to solve real problems in the real market environment. The proposed method has to be composed of well defined elements and relations between these elements to ensure that investors who will apply this method to help them solve their problems are satisfied with the recommendations this method will produce for them.

Primary objective of this research:

To develop a complex decision support method that will process the input data (supplied or collected) and reduce the large set of possible decisions to a significantly smaller set of alternative decisions based on the hierarchy and precise definition of the relevant criteria, requirements and objectives that are used for the evaluation of the supplied input data.

Secondary objectives of this research:

To develop support software application for the proposed method. For example applications that will allow to efficiently collect relevant information from internet databases of real estates and automatically process this information. To develop software application that will transform the input data and information about the relevant criteria into a fuzzy model that can be used by the chosen fuzzy logic software. Additional software is required to process the large amount of information that the fuzzy model outputs so that the evaluation of the resulting information is efficient.

To collect information about brownfield sites, generate a complex test fuzzy model and thoroughly test different scenarios with different sets of relevant criteria and conditions so the model is robust. Researched method has to be robust and reliable enough so it meets the needs of real decision makers and investors.

2 Theoretical foundations of this research

This chapter contains information about the scientific methods used in this research, related research and theoretical foundations of this research. To develop a complex system that helps decision makers to decide about purchase of a real estate requires input from several other research areas. This research is closely related to optimization, modeling, graph theory, soft computing, data mining, investing, multiple criteria decision analysis, fuzzy logic and other fields. The most important relations and things to consider during this research will be discussed in this chapter. This chapter contains discussion from three research papers that have been published during the initial phase of this research.

This research extensively uses modeling and simulations. Modeling is a comparatively new area of activity involving the marriage of ideas from various disciplines, and is an essential and inseparable part of all scientific activity. The professional modeler brings special skills and techniques to bear in order to produce results that are insightful, reliable, and useful. Modeling techniques include statistical methods, computer simulation, system identification, and sensitivity analysis. None of these, however, is as important as the ability to understand the underlying dynamics of a complex system. These insights are needed to assess whether the assumptions of a model are correct and complete.

The modeler must be able to recognize whether a model reflects reality, and to identify and deal with divergences between theory and data (Fortuna et al., 2001). If a certain process is too complex or involves such amount of elements that it is not possible to replicate the process for experimentation then it is necessary to use modeling and simulations. Modeling is a necessary part of this research. Fuzzy logic extensively uses modeling. Furthermore to be able to meet the requirements of future users of this research the predicted requirements of these users have to be simulated and tested. The system has to be reliable and flexible enough to meet the requirements of the real world decision makers. Modeling is defined as a process of generating abstract, conceptual, graphical and/or mathematical models. There are many different methods, techniques and theories about modeling and simulations.

The basic idea is to analyze a system and divide it into many elements that are well understood. Then a model is assembled from a set of these basic elements and relations. There is often a need to simplify relations and various factors that influence the behavior and functioning of a system. However this simplification must not lead to incorrect behavior of the system that is being simulated with the model. The results obtained from the modeling and simulations are not precise but they should be insightful, reliable and useful. A model is understood as a physical, mathematical or logical representation of a system of entries or processes. Model is a simplified abstract view of a complex reality.

Optimization is a term used in different areas. Many activities and processes use resources and there is a constant need to improve the efficiency of the utilization of these resources. In economics it is vital for a business enterprise to optimize the consumption of its resources. If there are parameters that measure input or output or a certain activity or process then calculations and simulations can be made in order to optimize this process. Optimization in economics is defined as the organization of technical and economic systems or processes in order to achieve the optimal state. Another definition is the search for best possible alternative of a certain process or decision. This research proposes a method that helps decision makers to make the optimal decision about the purchase of a real estate.

2.1 Scientific methods used in this research

This research is dealing with a complex problem that involves the processing of large amount of input data about the investment alternatives. The output of this research will influence the decisions made by the investors who will use the newly designed method for the evaluation of real estates. Several scientific methods have to be used in order to formulate and analyze the research objectives, gather and evaluate relevant information, create the fuzzy model, make simulations, test the model, interpret the results and formulate the recommendations to the users. Before the individual research methods are discussed it is required to define the term method.

Method is understood as a body of techniques for investigating phenomena, acquiring new knowledge or correcting and integrating previous knowledge (Seyler, 1998). Methods are usually formulated like a set of special rules which have to be followed in order to achieve the desired results. In science a method has to be based on gathering observable, measurable and empirical evidence. Data can be collected through observation and experimentation. Once enough data is collected analyzed research hypotheses are formulated and these hypotheses are then tested. Methodology is theory about methods of scientific inquiry. Methodology can be also described as the systematic study of methods that are, can be or have been applied within a discipline or just as the study or description of methods.

These individual scientific methods will be used in this research:

- Abstraction and concretization.
- Induction and deduction.
- Feedback.
- Modeling and simulation.
- Heuristic methods.
- Comparison.
- Analysis and synthesis.

Abstraction and concretization - abstraction is a process in which the essence and character of a certain object is being identified. For example it can be used to find similar traits of objects that are related in some way are grouped together. Abstraction may be formed by reducing the information content of a concept or an observable phenomenon, typically to retain only information which is relevant for a particular purpose. On the other hand concretization is the method of finding concrete elements from a group of objects.

Induction and deduction - deduction, deductive reasoning or deductive logic is a type of reasoning which constructs or evaluates deductive arguments. Each deductive argument aims to show that conclusion necessarily follows from a set of premises if indeed a conclusion follows from the premises then the deductive argument is valid. Deductive argument is sound if it is valid and its premises are true. It is important to understand that

deductive arguments are valid or invalid, sound or unsound but are never false or true. Deductive reasoning can be used to gain new knowledge from previously known information or knowledge. Deduction is one of the key methods in science. Induction also known as inductive logic or educated guess is a kind of reasoning that draws generalized conclusions from a finite collection of specific observations. In some cases not all information is known and so false conclusions can be made even if all the premises are true. If some event is rare and does not happen frequently by observing all events the observer can come to the false conclusion that no different event may appear.

Feedback - using feedback method to closely observe the changing results caused by changes in the input data or by changes in the model gives researches a good way to evaluate the impact of individual changes. The process of optimization and search for ideal values is not easy without constant testing and fine tuning parameters and algorithms. Even small changes in one operation can have significant impact on the processing time or accuracy of results. Feedback is therefore very important in science. In very complex and chaotic systems even small changes in a single input variable can produce very different results.

Modeling and simulation - modeling is a process of generating abstract, conceptual, graphical or mathematical models (Sinha & Gupta, 2000). There are various methods, techniques and theory about different types of specific modeling. A scientific model can provide easier way to understand a complex system because the elements in the model are simplified and the important relations between the elements are clearly observable. Modeling is an essential part of most scientific activities. The purpose of a model is to represent objects or processes in a logical and objective way. Model is basically a simplification of more complex reality. Model is not entirely precise and does not show all the details observable on the object or process for which the model is created but it nonetheless it is very useful as it show all the details that are important for the specific research which uses modeling technique. Modeling is very useful in cases where there can be no experimentation or direct measurement because of some reason - it may be impractical or even impossible to do some measurements or experiments. If the model

behaves realistically it can represent reality and the measurements and experimentation can be done on the model and with high probability these findings will be close to those that would have been measured on the real object or process. Simulation is the implementation of the model. Simulation can be static or dynamic. Dynamic simulation provides the researches with information over time. Simulation is a great way to do tests or analysis in cases where the reality can be represented by a model. Simulation has clear advantages because while it takes some time to analyze the system and build a model once the model is made many simulations can be done to get different results for different scenarios with different input parameters. So the combination of modeling and simulation gives researcher the possibility to find new and better solutions. Modeling and simulation are basic scientific methods used in wide array of scientific areas. Especially during last two decades with the development of new software and hardware modeling and simulation became widely used. This research uses modeling and simulation to find optimal investment alternative and to simulate possible future events to evaluate long-term impacts of the investment on business enterprise which makes the investment decision.

Heuristic methods - heuristics refers to the experience-based techniques for problem solving, learning and discovery. Heuristics are strategies using accessible information to control problem solving done either by humans or machines. Heuristic method is frequently used to identify an optimal solution as fast as possible. Not all problems are so complex and complicated that a simple solution cannot be found in a short time. Decision makers often have to solve large number of problems and there is not enough time to collect large amount of information and analyze each problem thoroughly - this would take a lot of time. Any problem that can be solved quickly gives the decision maker time to focus on solving more complex problems which cannot be solved easily. But before the decision maker knows that the problem is simple or complicated it is a good idea to try to quickly find the solution by heuristic methods. Easiest heuristic method is trial and error. This basic method can be used to solve wide variety of problems. Yet this simple method has to be used systematically and there has to be logic driving each trial and error.

Another heuristic method is to apply abstract problem to concrete example and try to find the solution for the abstract problem on these concrete examples. Or for example when trying to find a solution for a concrete example is too difficult it may help to try to solve a general problem which applies to the concrete example. This might also prove to be very useful as it may help to find new knowledge and information about the process or object.

Comparison - comparison can be defined as a process of examining resemblance or finding common traits and characteristics. While trying to find a new solution for the research problem it is very important to analyze and describe existing solution and when each new solution is found it is required to focus attention to the comparison of old and new result. Objective of most research tasks is to find better solutions - optimize some process, minimize costs, maximize profits or shorten the time it takes to solve some problem. In order to determine if the better solution was found it is essential to closely compare both results. It is also important to record all observations so after certain period of time each of the new solutions can be compared with all the other solutions that have been found during the research.

Analysis and synthesis - analysis is a process of dividing a complex topic, substance or system into smaller parts to gain a better understanding of it. Analysis can be also defined as the resolution into simpler elements by analyzing the whole. Analysis is frequently used in mathematics or logic. Analysis can be defined as a process of isolating individual elements of something so that it can be easily explained or reconstructed. In decision making before analysis can be made. It is important first to identify the decision problem. Once this decision problem has been identified it can be analyzed. Analysis can be done from several different points of view in order to discover all important aspects and relations are discovered. Thorough analysis leaves no important detail, factor and dependence unchecked. The process of reconstructing a system from its identified components is in turn called synthesis. Synthesis refers to a combination of two or more entities that together form a new complex entity. Synthesis can be also defined as the formation of something complex or coherent by combining simple elements.

The conducted research brings new views to several areas and examines the relations that have not been studied before. The results of this research will be also usable by the real world investors. It is therefore very important to analyze the use of these scientific methods to ensure that no important steps are omitted or incorrect conclusions made. Modeling and simulations play a vital role in this research because they allow to thoroughly test the applications and processes to ensure that the designed system is reliable and flexible enough for the use in the real world.

The research problem has to be analyzed and then the new solution of the problem has to be synthesized. Feedback plays also an important role during the work with the fuzzy model and the simulation. Heuristic methods will be used to try to find an easy way to find the optimal investment alternative in shorter time than it takes to make the fuzzy model. Also the individual results and solutions will be compared side by side to determine which solution saves the most time, resources or computation time.

2.2 Literature review and related research

Following chapters discuss important details found during the literature review phase. This chapter contains a list of scientific papers related to the application of fuzzy logic in economics, real estate investment and application of soft computing in economics. Extensive search for research papers focused on the application of fuzzy logic in the area of brownfield redevelopment was conducted and most research papers found used fuzzy logic in other areas such as logistics, forecasting, stock trading etc. Only one paper was found which directly relates the use of fuzzy logic with brownfield redevelopment. Fuzzy logic is suitable for the use in economics particularly because of its ability to work with models containing unknown or imprecise information. Fuzzy logic is used often to work with the dynamics of stock exchange by other researchers. It is also used for the predictions about the future development of chosen variables and to examine the complex dependencies between economic variables. Two colleagues from the Faculty of business and management also lead by my research adviser prof. Dohnal successfully applied fuzzy logic in economics. These two dissertations are listed below. One research paper related to brownfield redevelopment and utilization of fuzzy logic for decision making support was published in 2009. This research paper discusses the use of fuzzy real options instead of the traditional net present value method which is used currently by most investors. Even though NPV method has a list of disadvantages, it is easy enough for most investors to calculate themselves. This research proposes a more complex method which uses more information about the investment alternatives and outputs complex information about the individual brownfield sites and the measure of their similarity to other brownfields.

Even after an extensive search for similar application of fuzzy logic - no research paper which uses a model similar to a model proposed in this research or a hierarchy of variables which is used in this research was found. The objective of this research is not only to produce a theoretical proof that this approach is viable. But also to offer the newly researched method as a service to real investors. This new decision support method is offered as a service and not as a software application because the process is too complex and once programmed it would no longer offer the required flexibility.

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2.3 Conditions influencing this research

This research is influenced by several conditions. Market environment in Czech Republic is evolving and there are many possibilities for investors who have free resources. The prices of real estates are steadily increasing and it is possible to expect that they will be comparable to prices in other European countries. In the long run investors can sell the purchased real estate and make a profit. Many real estates which are currently available for purchase are strategically located and their prices are very reasonable. For an investor with a business plan these real estates are great possibilities for future growth and making long term profits. There are also many brownfield sites available for purchase. A lot of large scale manufacturing and processing facilities ended their operation altogether or were forced to limit their operations during the past two decades. These brownfield sites are now available for purchase.

Local municipalities and governments offer a helping hand to investors who have a plan to bring these sites back to life and remove the existing contamination. To redevelop a brownfield site means to improve the quality of life to all surrounding inhabitants. Ecology plays a very important role in the EU and there are new laws and regulations that need to be taken into consideration. Future ecological regulations will be even stricter than the current legislation. Ecological aspects of the decision making process related to brownfield redevelopment play an important role in this research. There is currently no standardized approach to efficiently evaluate a large number of investment alternatives while considering their suitability for redevelopment. This research aims to facilitate the process of finding suitable brownfield sites for redevelopment. Majority of business enterprises are struggling right now due to the financial crisis. Large number of enterprises is dependent on the car industry – it is necessary to diversify operations and become less dependent and more flexible. There is a strong competition on the market and it will become even more difficult to succeed on the future markets. There is a need to wisely utilize the available resources. Even small and medium sized enterprises will have to use sophisticated methods to analyze and evaluate the steadily growing amount of available information as new technology and research becomes available – the use of newest methods and approaches brings the competitive edge to successful enterprises.

Currently the investor often does not have a sophisticated software available which would simplify the decision making process about the ideal investment alternative. Classical approaches like for example MCDA or financial indicators are used in order to find the ideal investment alternative. The process of data collection and analysis is often slow and requires a lot of manual work and time. This research aims to facilitate and accelerate this process – extract more information from the available data and process it more efficiently. Although the proposed method is complex the time required to perform all necessary processes is relatively short – when considering that a large number of investment alternatives can be analyzed at once the new research has clear advantages over the regular approaches.

Disadvantages of commonly used approaches

- Investors consider only a small set of investment alternatives located close.
- MCDA approach is complex and requires a relatively long time.
- NPV approach is influenced by the estimates made by the investor - that significantly impacts the obtained results.
- The collection of required information about investment alternatives is performed manually. Some investment alternatives are excluded from the process only because it would require too much time to collect and analyze the information about these sites.
- Individual decision maker does not perform such complex decision making problems related to brownfield redevelopment often unless its employer is a company which focuses on brownfield redevelopment. Therefore most decision makers do not have predefined methods they can use from the past.
- If all the information is processed manually without special software the time required for the whole process is a limiting factor.

This research aims to address these problems and develop a complex method that will be offered to investors as a service which helps them to find ideal investment alternatives.

2.4 Small to medium sized enterprises

SMEs or small and medium enterprises are companies whose number of employees or turnover falls below certain limits. Small and medium enterprises play a very important role in the European Union. This research is conducted with the objective to facilitate the selection of suitable real estates for SMEs. Micro, small and medium-sized enterprises are socially and economically important, since they represent 99 % of all enterprises in the EU and provide around 65 million jobs and contribute to entrepreneurship and innovation (OECD, 1998). Globally SMEs account for about 50% of GDP. SMEs have significantly less resources then large international corporations therefore the decisions about long-term investments are vital for them.

What makes the investments even more difficult is that SMEs often do not have enough time and resources for thorough analysis of all available alternatives. One of objectives is to help SMEs improve their investment decisions. SMEs play also a very important role in emerging markets. For example in India the SMEs account for approximately 40% of total production and approximately one third of total exports of Indian economy. Major advantage of SMEs is the low capital costs, flexibility and employment potential. SMEs can react faster in the changing market (Lloyd-Reason & Sear, 2007). When new market niche appears it can be easily targeted by a brand new small flexible company which was founded especially to satisfy the new segment.

Another interesting fact is that the average labor intensity in small to medium sized enterprises is significantly higher than the average in large enterprises. Typically labor intensity in SMEs is about 4 times higher. A single manager in a small company has a better overview of the company and is more flexible - there is also less administration required to run a small company and changes can be implemented in shorter time and more often. In a flexible small company people are used to work in a changing environment and do not oppose changes because they do not see them as threats to their routine. SMEs are defined differently in different parts of the world some countries consider a business enterprise a SME when it has less than 250 employees - in other countries SMEs are considered to have less than 100 employees.

Even smaller company with 10 and less company is called micro enterprise or small office (SOHO). Another criterion how to determine which business company is a SME is by turnover or by the amount of assets. The different threshold which is being used in different countries makes it more difficult to research individual economies when they do not agree on the concept of SMEs. Small enterprises have several advantages. For example in recent years structural funds of the EU funded network of researches across the member states of the European Union in order to identify and describe the best practices the companies use. This database of best practices contains valuable know-how and methods which can be implemented in other companies and can lead to significant improvements and cost saving. Implementing changes in SMEs is easier, faster and does not require so many resources as implementing changes in a large corporation (Lenihan et al., 2010).

Major advantage is flexibility - major disadvantage is that small enterprise does not have enough resources to fund own research and development and the technology the company can purchase can be limited by the prohibitively high purchasing price of some technology. Small enterprise cannot afford to buy the newest and most sophisticated technological process as this often requires the newest measuring instruments, manufacturing robots, access to laboratories with qualified researches and so on. Another major advantage can be when several SMEs agree to collaborate on a certain project which allows them to join their efforts and achieve desired goals in shorter time.

However collaboration between business companies in a competitive market environment can be difficult because of the terms and the required negotiations and agreements that have to be made. But even so once the SMEs agree to work together the advantages they can gain can be very positive. For example they can share the investment costs and risks. They can leverage resources across the supply chain. They can also reduce lead times and they can increase market responsiveness. Collaborating enterprises can also access specialist resources - share equipment, know-how, facilities etc. And they can also exploit the economics of scale as larger amounts of products are being produced.

Collaboration can have positive impacts on sales, it often leads to cost reduction, productivity improvements, quality improvement, new technology is accessible and new markets are accessible (Fingleton et al., 2003). However many collaborations fail because often the long-term details are overlooked in the initial phase of negotiations. The most commonly used collaboration type is the supply chain collaboration - but it is also the most frequently misunderstood. Enough care has to be taken to choose the right partners for the collaboration.

It also takes to precisely define the key roles and rules that will be respected by all parties. Often mistakes include objectives that are not shared by other companies. One company can lose its independence and may become dependent on other companies. It is also important to be open and be able to learn from others. Another important thing to consider is that some information has to be kept secret and not shared between companies because they are still competitors on the market. Lack of leadership or trust can be also serious mistakes parties can make during the collaboration.

It is also clear that there will be differences between the two companies. Also building a partnership requires certain resource investment for example workers have to be trained, managers have to invest time into negotiations. Some researches indicate that it may take several years before cooperation operates effectively. This research is aimed specifically for the needs of SMEs - large real estate investments are difficult for small enterprises with limited amount of resources so extra care has to be taken in the decision making process. Managers of SMEs agree that any help and support they can use for finding the ideal investment alternative is very valuable and provides competitive advantage. Because there are so many SMEs on the market in the EU and because there are so many available investment opportunities on the market - the objective of this research is to facilitate the decision making process about investment into real estate especially for SMEs.

2.5 Investing

The objective of real estate investment process is to find and choose the optimal investment alternative considering all relevant factors and variables. There are several very important things to consider when deciding about future investments. According to (Brueggeman & Fisher, 2004) these things are among others:

- Growth.
- Risk.
- Funding.
- Irreversibility.
- Complexity.

From the point of view of the growth of a business enterprise - effect of the investment decision extends into the future. Such long-term decisions influence the direction and the pace of the growth. Wrong investment decision can be so serious that it can even endanger the survival of the business enterprise. Unprofitable expansion can result in significantly increased costs. On the other hand the insufficient investments can limit the chance to maintain or expand the market share (Samuelson & Nordhaus, 1995).

Risk - long-term investments can also increase the risk complexity of a business enterprise. Large investment means fluctuations in amounts of available resources and this can mean increased risk. Investment decisions are important especially for SMEs and influence the character of a whole company.

Funding - real estate investments often require large amount of financial resources. Firm has to carefully and strategically plan its investment decisions. Funding has to be procured in advance from internal or external sources. It is a difficult task to ensure that enough resources are available not only for the investment but also for random unforeseen events.

Irreversibility - most investment decisions cannot be undone and are in their character irreversible because it is very difficult to find a buyer for a purchased property once it has been acquired. The company will usually incur heavy losses when it tries to sell assets shortly after they were purchased.

Complexity - investment decisions are among the firm's most difficult decisions (Kau & Sirmans, 1985). There is a need to predict the future development on the market and assess the individual possible future events that can occur. Especially on the market this is very difficult - there are many unknown factors influencing the market and market cannot be easily predicted - market itself is very complex. Also it is required to estimate the future cash flows. Economic, social, legislative, technological and other factors can influence the future cash flows just like competitors on the market. Therefore complexity of the investment decision must not be underestimated.

In some cases decision based on known variables may be skewed and not optimal. Some important details may be unknown and they might have significant influence on the final decision. If the decision makers would have this unknown information they could make a completely different decision. Some information can be hidden on purpose by third party in order to achieve a higher selling price or to conceal some problem. Such scenarios also need to be taken into consideration.

Therefore it is necessary to focus enough attention on the decision making process not just in the perfect conditions when all information is correct and easily available but also in the conditions of uncertainty with unknown, incorrect or misleading information (Byrne, 1996). Real estate investment is a very important and sensitive area of the operation of business companies. Investments are often long-term and require a significant amount of resources. First there has to be a thorough analysis of the current situation in the business company and if there are no other options how to expand the existing capacities or increase the efficiency of processes inside the company in order to achieve set goals then it is time to consider investing into new building complex or into a new brownfield.

The decision to buy new real estate can have a very positive but also a very negative impact on the company. One of the serious mistakes is to focus too little attention on the initial research of the inner needs of the investor. It has to be clear what the investor needs – what is the objective what does the investor aim to achieve with the investment. In some cases it might seem like investing into a new manufacturing plant is inevitable but it may happen that after considering other options another solution might be found that costs less and provides almost the same or equal profit. Initial research of the needs is therefore very important. Once the decision makers come to a conclusion that the purchase of new building or plant has to be done it is time to do a research of all possible alternative investments. For this it is necessary to define a set of parameters that are relevant for the investor (McLean & Eldred, 2005). Without this set of relevant parameters the decision making process might be negatively influenced by bias of one of the decision makers for example. Most decision makers tend to use their previous experience in order to find the optimal alternative investment. For example a negative experience with some type of property might make the decision maker to prefer other alternative investments that seem to look much better due to his or hers previous negative experience. If this bias is not explained and decision makers do not know about it or do not discuss it the resulting decision may be far from optimal. Another important detail to consider is that the investment is not over the day the property is signed over to the investor. Investor should have a plan how to quickly accommodate the new capacity to suit own needs.

Such accommodation of course costs additional resources. Good manager knows the impact of the decision even before the decision is made. Accommodation of the new real estate should be therefore always possible even if some unexpected events occur in the future. There might always be a risk that some equipment might not be available or some changes to the structure or surrounding of the property might be met with opposition of the local community or new legislation might hinder the planned changes etc. Therefore even such scenarios for each alternative investment must be taken into consideration.

Thinking about things that might occur in the future ensures that there are no unexpected negative consequences of the investment. Real estate appraisal focuses on the questions of price and value (Reilly, 2000). Basically there are three different things to consider:

- Price.
- Market value.
- Investment value.

Market value is different than price. International valuation standards committee defines the market value as: „The estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arms-length transaction after proper marketing wherein the parties had each acted knowledgeably, prudently, and without compulsion.“ Another term used in real estate appraisal is investment value. Investment value is the value to one particular investor. For different investors one real estate can have different investment value (Sirota, 2004). This value is usually higher than the market value of the particular property. If the investment value is lower than the market value then this investment alternative is not optimal and should not be chosen. In the analysis phase a set of relevant parameters has to be defined by the decision makers in order to objectively evaluate all investment alternatives. Investor has to have a clear set of quantifiable requirements. Each investment alternative is assessed and scored based on these criteria. Some criteria may be more important than others. Therefore a clear hierarchy of the relevant criteria should be defined (Götze et al., 2007). Each criterion can have different weight and can have different impact on the final decision. This process is complex but ensures that all available data are evaluated systematically.

Investors can have a different set of relevant parameters on the possible investments but in most cases variables like area of the property, distance from the headquarters, availability of specialized equipment, future extensibility, required approximate initial accommodation investments, availability of qualified workforce in the vicinity and other parameters. The designed fuzzy model includes the parameters most investors will probably need when evaluating a brownfield site.

2.6 Investment evaluation and financial indicators

Investment evaluation is a very important phase during the decision making process about long-term investments (Geddes, 2002). The buyer has to make sure to choose the right investment opportunity. There are many different investment opportunities and it is very complex to evaluate the firm's long-term strategic goals and decide which investment opportunity is right for the company. First step to make is to collect the basic information - in this step the decision makers have to make sure that all relevant and important information is available for the evaluation. Identifying the key needs of the business enterprise is also critical. Due to the irreversibility of large investments there is no space for incorrect assumptions and conclusions rooting in missing or incorrect information collected about the investment opportunity. Before the investment is made the buyer has to create a very comprehensive business plan. Company has to have clear strategic objectives. Also the decision makers have to predict the possible scenarios about what could happen on the market and what could negatively influence the investment not only at the present time but also in the future. Evaluation of the investment opportunity itself has several phases. First it is necessary to clearly define and list goals of the investment. Managers have to be sure that they need new capacities and investment is not avoidable by any other means. Large and long-term investments are always risky and in a sense can endanger the operation of a business enterprise as it becomes more vulnerable. Estimating the payback period for the investment is vital - large investment costs a lot of resources and often company has to concentrate resources and funding it would use elsewhere to make the investment. It has to be clear when the investment project will be profitable - how long will it take before the investment covers its costs and starts to generate profit for the investors.

Comparing the investment opportunity with alternative investment opportunities on the market is also a very important step - all other alternative investment opportunities have to be carefully examined and compared before the final decision is made (Brown, 2005). After the set of all possible investment alternatives is reduced the decision makers have to create a reasonable financial plan to ensure that enough funding is available and related costs will not endanger the operation of whole business enterprise. After the financial plan has been made it has to be reviewed by independent professional advisers.

Evaluating the investment opportunity risks is also a very important phase of the decision making process. Long-term investments are risky especially for small to medium sized enterprises - which usually have significantly less resources than large companies. Large corporations can easily allocate enough resources to make even large investment projects reality without the need to borrow additional resources from banks and other institutions. Calculating the risk and potential loses of the investment project is vital. Any promising investment project can lead to heavy loses if something unexpected happens. Of course the investors have to calculate their plans so that they have reserves to cover the impact of unexpected negative events which influence their investment. It is also required to get enough information and to settle all the regulatory requirements - these requirements may include environmental, technical, zoning, legislative, technological and other requirements. Investors also have to determine the financial and technological reserves that can be used for the investment project.

Large companies have more available resources and can more easily obtain new resources from banks. The smaller company the fewer available resources it usually has and it is also more complicated to borrow money for investment projects. Banks are closely examining the business plan to see what risks can endanger the investor and can cause the business not to be able to repay debts. During last two decades the banks became more careful when lending financial resources to SMEs. Large percent of their business plans failed and the companies were not able to repay their debts. It is also necessary to calculate the potential loses for the worst case scenario.

It is easy to plan for the best case scenario but such plans are also dangerous - it is also necessary to make a plan for worst case scenario and investors can expect that with high probability the investment will be in the bounds defined by the best and worst case scenario. Legal aspects of the investment project have to be confirmed with independent professional advisers. After all these steps it is required to secure the investment by assets and then to insure the assets so unexpected development cannot negatively impact the investment project.

Investments are usually appraised with the help of financial indicators (Vance, 2003). From the point of view of the financial indicators it is necessary to realize several different things. Time value of certain investment is very important. It is known that the time value of the same amount of money today is worth more than the time value of the same amount of money received in the future. Investors can take into consideration the growth of prices on the real estate market. Especially in the Czech Republic investors can purchase real estates for prices that are much lower than they would pay in for example in Germany or in the UK. But there are also differences in purchasing power of customers, costs of services and average incomes of employees. Next important thing to consider is the measure of true profitability - to measure the true profitability of the investment project the investors have to calculate all cash flows occurring over the entire life of the project and so the true worth of the investment project can be determined. It is also important to calculate the costs, profits and value of the investment from the point of view of the shareholders (Ventolo, 2001). First non-discounted cash flow method is payback period. Payback period is frequently used because of its simplicity. It is calculated by dividing initial investment by annual cash inflows. Accounting rate of return is another method and it is calculated as dividing the average income by average investment. Investment should be accepted when the accounting rate of return is higher than the minimum rate established by the investors. Return on investment (ROI) is the performance measure used to measure the efficiency of investment project. It can be also used to compare different investment alternatives. The calculation of ROI requires the division of the difference between gains and costs of the investment and cost of investment. The result of this calculation is a percentage or ratio. Internal rate of return (IRR) is a popular method because it calculates the profitability as a percentage and offers a great possibility for comparison with the opportunity cost of capital. IRR has several advantages for example it recognizes differences in the time value of financial resources. Another advantage is that it takes all cash flows during the entire lifetime of the investment project into consideration. From the point of view of the shareholder value - whenever the IRR is higher than the opportunity cost of the capital the shareholders wealth will increase. Profitability index (PI) is calculated by dividing present value of cash inflows by the initial cash outflow. If the PI is greater than one the investment project should be accepted.

Net present value (NPV) is a frequently used economic method of evaluating investment proposals. It is discounted cash flow method that recognizes the time value of money. It postulates that the cash flows that appear during different phases of the lifetime of the project differ in real value and can be compared only when the equivalent of the present value is determined. The NPV calculation has several steps:

- Cash flows of the investment project should be forecast realistically.
- Discount rate has to be calculated to discount the forecast future cash flows, the discount rate reflects the opportunity costs of capital and the expected rate of return should the capital be invested in some other way - it is also necessary to calculate the expected risks related with the alternative investments.
- Present value of cash flows should be calculated using the opportunity cost of capital as the discount rate.
- Net present value (NPV) should be calculated by subtracting present value of cash outflows from present value of cash inflows. The investment project should be accepted if the NPV is positive.

Positive net present value contributes to the wealth of the shareholders. Positive NPV tells investors that the project cash inflows are higher than they would be if the capital would be invested into other alternative investment. The main idea is to carefully compare the investment alternatives and to calculate the real value of the future cash slows as it differs from the cash flows at present time.

The investment project should be accepted when the NPV is positive, it may be considered as positive when the NPV is close to zero and the investment possibility should be rejected when the NPV is negative. NPV can be used to select between several different projects that are mutually exclusive. The investment project with the highest NPV should be chosen by the investors. It is also possible to directly grade the investment alternatives by their calculated NPV. The net present value method is in concordance with the objective of shareholder value maximization. Therefore the NPV is a very useful tool for shareholders to examine and evaluate the investment decisions made by the company.

But the NPV indicator has also several problems and disadvantages. One significant problem is the cash flow estimation - NPV calculation requires estimated future cash flows but it is difficult to make good estimates of the future cash flows. It is also difficult to precisely measure the discount rate - the discount rate can be also only estimated.

Caution needs to be applied if the NPV method is used to evaluate several investment alternatives with different parameters for example if the lifetime of one project is several times longer than those of the other investment projects - NPV can lead to results and recommendations that can hide the differences between the investment alternatives. NPV also depends on the discount rates - should the discount rates be calculated based on different assumptions it influences the results of NPV.

In this research the comparison of different investment alternatives is very important in order to determine which investment alternative should be chosen by the investor. Each of the alternatives will be described by a set of about twenty parameters which are then processed by several different methods based on fuzzy logic. It is very useful to compare the commonly used financial indicators with the results of the designed method based on fuzzy logic. In ideal case both methods should produce same results - select optimal investment alternative. But the newly developed method which is a result of this research provides overview of all different variables and allows investors to weigh the parameters differently. Clustering the investment alternatives into groups allows the discovery of common traits between different alternatives.

2.7 Brownfields

Brownfields are abandoned or underused industrial and commercial facilities available for re-use. Expansion or redevelopment of such a facility may be complicated by real or perceived environmental contamination (Davis, 2002). This research is partially focused on brownfields and on ecological aspects related to brownfields. It is very important to reuse existing real estates. Due to the changing market environment in Czech Republic in the past two decades there are many capacities that are not used. According to the National strategy for brownfield redevelopment published by Czech Invest there were close to 2300 brownfield sites in the Czech Republic with a total area of 10 300 hectares in 2008. Further information about brownfields in the Czech Republic can be found in (Czech Invest, 2008). These numbers include areas used for agriculture. Out of the 2300 only 176 sites were identified to be contaminated. It is possible to purchase and redevelop these brownfields. However there are specific factors to consider like for example the contamination of soil or investments that have to be made to meet the recent more strict legislation related to ecology. Soil and groundwater under the brownfield may be contaminated by pollution or hazardous waste.

Brownfields exist mostly in industrial sections of cities or are close to abandoned factories or other polluting operations. In most cases it takes several years to repair the damages done to the environment. Typical contaminants that can be found in most brownfields can be hydrocarbons, pesticides, asbestos, solvents or other chemicals (Surhone et al., 2010). The contamination may cause health risks and special measures have to be taken in order to reduce or eliminate this contamination. To remove the contaminants can be very costly (Hazelton & Murphy, 2011). Therefore the related costs have to be calculated into the future costs should the investors decide to purchase polluted brownfield. Because the brownfields are located frequently close to other factories or industrial areas the logistic infrastructure does not require as much future investments as for example when it has to be build from scratch when the business company decides to build a brand new plant.

Brownfields offer some advantages but also have some disadvantages that have to be taken into consideration. States and governments actively encourage redevelopment of brownfields - as the economy gradually shifts from agriculture to industry and finally to services there are more and more available brownfields that wait for future investors who will use their innovation and know-how to reuse the existing capacities to bring future prosperity. EU legislation is very strict and what was allowed in the past became illegal.

The objective of the EU is to influence business enterprises to be green and not to damage or exploit the environment like they were used to in the past. It is in the common interest of people living around brownfield and of the government to support the redevelopment of brownfields. Governments try to find easiest and least expensive ways to clean the contamination and create environment for new investors who return the employment for people living in the area. Venture capital firms and insurance companies invest into brownfields because it is a great investment opportunity which could bring large profits in the future. New research related to the redevelopment of brownfields brought new innovated remedial techniques into use. For example bio-remediation is used.

New methods utilize naturally occurring microbes for cleanup of contaminated soil (National research council, 1999). Another innovative way to extract heavy metals from the soil is to use phytoremediation this method uses deep-rooted plants to naturally extract the minerals from the soil as the plant grows. When the plants reach maturity they contain the dangerous heavy metals and are disposed of along with other hazardous waste. Ideal post-redevelopment use for brownfields is housing. To build new houses in an area previously used for industrial production saves arable land. Past industrial complexes are located relatively close to the city centers so once the new houses are build inhabitants do not have to spend so much time commuting to work in the city center. There are many ways to efficiently use the brownfield site once it has been cleaned and brought back to life. Investors often learn from brownfield redeveloped in other counties (Adams et al., 2010).

Although redevelopment of brownfields requires significant amount of resources and time it often proves to be a great investment. This research is aimed specifically at the reuse of brownfields. As the economy changes there are many available interesting sites for purchase for very good prices. But investors have to carefully analyze and examine each individual brownfield because the costs related to the remediation and redevelopment can vary in a great way. Investors can encounter a lot of missing or unknown information which may have been concealed intentionally by the previous owners who want to sell the property for the highest possible price regardless of the contamination.

There are also certain barriers that hinder the redevelopment of brownfields. One of the barriers is that the cost of cleaning the contaminated brownfield is much higher than the land would be worth after removing the contaminants (Hula & Bromley-Trujillo, 2010). Because of this many brownfields lie unused for a long time as no investors are willing to invest so much resources and effort into redevelopment and instead they choose to build their factory on arable land. New government programs aim to invest into the research of existing brownfields and help investors to find suitable areas for their future business plans. Such research can find previously unknown hidden tanks containing hazardous waste. Such discoveries significantly increase the costs of the redevelopment. Valuation of brownfields requires specialized appraisal analysis techniques.

2.8 Benefits of brownfield redevelopment

In this chapter the individual economic, environmental and social benefits of brownfield redevelopment are discussed. Most brownfields are contaminated and a significant investment has to be made in order to remove the contamination. Because of this some investors avoid brownfields and prefer to build new facilities in rural areas. However each such new facility will become a brownfield site in the future. Without brownfield redevelopment there will be less rural areas which are not contaminated but a lot more contaminated brownfields in the future (Doick et al., 2006). Such development is obviously very negative, not sustainable and enough attention should be directed toward this problem.

This research is intended to show the potential benefits the brownfield redevelopment may bring not just to the investor but also to the community and economy. Various impacts the brownfield redevelopment has on different parties is discussed also in (Schadler et al., 2011). First the individual economic benefits of brownfield redevelopment will be discussed. Brownfields have usually a very good infrastructure that can be easily upgraded. This upgrade may be possible for a fraction of the costs it would take to build new roads, electricity lines and other necessary infrastructure. Brownfield often have a strategic location. Brownfield is often a large area with a very good infrastructure usually located close to larger cities and other industrial facilities. Many investors agree on the fact that the location of a real estate is critical and influences significantly almost all costs related to logistics. Industrial plants in the past were located often near the city limits. As population grew cities expanded and by the time the plant was obsolete the city limits were already far beyond the brownfield site. Many brownfield sites are therefore located much closer to the city centers than new facilities. If a brownfield site is surrounded by houses people live in the contamination of the brownfield site may be dangerous to local community. Brownfields may be purchased for a relatively low prices when compared to other facilities available for sale. Supply and demand directly influence the price. If a brownfield is contaminated then the price has to be lower than the price of a real estate which is not contaminated.

The decontamination is frequently very expensive. Investors therefore do not purchase a brownfield for a high price – unless this price is lower than the true investment value the real estate has for the investor. Brownfields are often located in urban areas and close to large cities where it is not difficult to find and hire qualified workforce. Qualified workforce may be required by the investor in the near future as soon as the redevelopment is finished. For example the investor can build a new manufacturing plant that will create hundreds of new jobs (Dull & Wernstedt, 2010). Often a special funding and subsidies are available for the redevelopment of brownfields.

Dozens of brownfields may be located in a larger city and therefore it is not possible for the municipality to finance the redevelopment of all brownfields. Instead the municipality relies on investors and promotes the redevelopment of brownfields by providing various incentives, subsidies, or low-interest loans etc. Redevelopment of brownfields leads to the creation of new jobs. Even during the redevelopment new jobs are created as the redevelopment is often a complex and long-term process. Soil has to be removed, harmful substances have to be secured and extracted from the site. After the contamination is removed the construction of new buildings and facilities begins. Once the new facility is built new jobs are created as soon as it starts to operate in case it is a manufacturing plant for example.

Local community may benefit from possible higher incomes in the future as more work opportunities are available and employers have to compete for qualified workers. New competitor between employers often means higher wages for workers as they are ready to change their employer in exchange for a higher wage. New commercial activity in a certain area means also higher tax revenues. If there is an abandoned brownfield site it does not generate tax revenues for the state. To make things worse the contamination may even be harmful for local residents. If this brownfield site is purchased by the investor and the redevelopment starts instantly there are tax revenues and in the future the tax revenues may increase very significantly as hundreds of jobs may be created in the new plant which may be built there. State therefore provides even tax related incentives for the investors who decide to redevelop brownfields.

Redeveloped brownfield sites often positively influence the price of adjacent real estates. Investors tend to pay less for real estates located in the vicinity of contaminated brownfield sites. The price of such real estates may therefore be much lower than it would be if the brownfield site would not exist. After the brownfield is redeveloped the price of adjacent real estates increases significantly (De Sousa et al., 2009). This positively influences the community and investors often find support from the community. The good will is very beneficial and it is something that cannot be bought. The redevelopment itself creates new jobs and investments into the area. If state wants to support employment in a certain area it is a good way to promote this activity as it will create new work opportunities and bring new investments into the focus area. The value of the site increases significantly after the redevelopment. This is related to the costs of decontamination. Once the contamination is removed and the site is upgraded the value of the site can increase several times. This is also very positive for the investor. To have a strategically located site with good access to local workforce, much closer to the city center than if the facility would be built in a rural area outside of the city limits is a good combination of factors that can secure the success of the future strategic objectives of the investor. Government promotes the redevelopment of brownfield sites through state and local tax incentives, technical oversight and technical assistance, subsidies, grants, lower-interest loans and other means. In some cases qualified remediation costs can be written off if the legislation allows it.

Environmental benefits include among others these effects. Existing contamination is secured and gradually removed, health and safety hazards are eliminated. Available capacities are utilized more efficiently – the productivity of the land increases. If more and more rural areas are used for industrial facilities in the future, large part of current rural areas may be converted into abandoned contaminated brownfield sites. The rural area chosen for the new facility would so be irreversibly converted and the surrounding environment would be affected by the presence of this new facility. Such progress is obviously not sustainable. It is sustainable to redevelop existing brownfields instead of building new industrial facilities in rural areas. A study has shown that if a brownfield of a certain area is redeveloped it saves several times larger area should the facility be built in a rural area.

This is caused by the fact that the new facility would require new roads, parking lots, electrical lines etc. EU and local government support the revitalization of brownfields as the previous owner did not remove the contamination and the site poses a threat to the environment and local community. It may also be too expensive for local government to finance the redevelopment. The price of decontaminated brownfield would be lower than the costs of decontamination in some cases. Therefore it is not economical for local government to redevelop brownfields located in a certain area. The resources are often more needed elsewhere. Once the brownfield site is redeveloped any future groundwater contamination is avoided. The sooner the brownfield site is redeveloped the better for the environment.

Social benefits include among others these effects. People living close to the brownfield site welcome the efforts undertaken to redevelop existing brownfields which directly improves the environment they live in. People prefer not to live in the vicinity of a contaminated brownfield site that may negatively influence their health and wellbeing. If an investor decides to redevelop the brownfield and remove the contamination the lives of local residents are improved and they welcome the redevelopment. Investor often negotiates with the local community and government about possible costs and benefits of the revitalization project (Wang et al., 2011). Redevelopment is perceived very positively by local community in most cases and creates good will from the community. That is something very valuable for the investor who plans to hire employees from that area in the close future. Every community requires a sufficient number of jobs available for the local residents. If there are not enough jobs available it may lead to economic and social problems in whole community. The redevelopment process itself is a long-term and complex process - it creates new jobs. Additional jobs are created once the process is finished. New jobs mean more opportunities for local community and even higher incomes as there is more competition between employers. These are related and very positive impacts of brownfield revitalization. Creation of new jobs in urban areas benefits local residents as they do not have to travel long distances to work in new facilities built in rural areas.

Workers prefer to work in a brand new facility created on a brownfield site because it is much closer to where they live. As cities grow the time it takes to commute increases. Redevelopment of brownfields helps to address this problem at least for a part of local residents who find work in the new facility do not have to commute far. This research proves that there are many potential benefits of brownfield redevelopment.

2.9 Sustainable development and ecology

The redevelopment of brownfields is closely related to frequently cited topics such as sustainable development and ecology. Protecting the environment and making the economic system sustainable and balanced is a long-term objective of the European Union (OECD, 1998) . Sustainable development is a way of resource utilization which allows to reach two basic goals simultaneously – to meet human needs and to preserve the environment. In the past the natural resources were not used this way. Needs were met but the way how these needs were met was not sustainable – it was not possible to continue to use the resources this way in the future. Once the resource is exhausted the operations requiring this resource cannot continue unless some change in the process is made (Baker, 2006). New strategy aims to use resources wisely in order to meet the needs not only in the present but also for future generations. Sustainable development is frequently defined as the development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Jackson, 2009) .

Commercial enterprises often prefer short-term profits instead of long-term prosperity. Even if the profits originate from unsustainable practices and use of resources. Obviously the whole society suffers because of these companies that think that profits are more important than the long-term well-being of the whole society and economy. In the past the environmental impact of human activity was not observed. Resources were plentiful and there was no need to reduce consumption of some resources because the resources were easy to obtain and inexpensive. As the world population increases it becomes evident that there is not enough vital resources such as oil, gas, coal, metals or water if they are consumed not sustainably (Maples, 2005). These vital resources were not used wisely in the past. All resources have to be used wisely in order to secure them for future

generations. Economy and ecology have to be balanced. Environmental sustainability is closely related to economic sustainability. There are two key concepts – the concept of needs and the concept of limitations. Humans have needs and natural resources are limited. In order to steadily satisfy the needs the use of resources has to be optimized. Sustainable development has three dimensions: environmental, economic and social. Some process is sustainable only if all the needs from these three criteria are met at the same time. That is why it is difficult to make some process sustainable.

There are often competing goals yet only a method that simultaneously allows economic prosperity, environmental quality and social equity is sustainable (Gechev, 2005). In some cases the strict requirements cannot be met – for example in poor countries it is unattainable to use the newest technologies that protect the environment because it is too expensive to implement these technologies. Yet long-term objective is to make every process sustainable even if the profits decrease. Protecting the environment is more important than the short-term profits. Human society faces many challenges as it was built during the era of unsustainable development where environmental questions were much less important than they are now. The consumption of resources has to be balanced with the nature's ability to replenish these resources (Faucheux et al., 2010). If the consumption is faster than the use of this resource cannot be sustainable. Steady state economy is when the rate consumption is equal to the rate the nature replenishes the resource. Environmentally sustainable consumption is when the rate of consumption is lower.

The redevelopment of brownfield sites is clearly more sustainable than building new industrial facilities on land that was not previously used for industry. Even if it is more expensive to decontaminate the brownfield site and it takes larger amount of time – the redevelopment of contaminated brownfield is more ecologically sustainable. After the redevelopment the contamination does not pose a threat to the environment anymore. States promote the redevelopment of brownfield sites because there are many brownfield sites and it would require significant amount of resources to clean all brownfield sites. State usually welcomes any private investors who plan to redevelop brownfields and offers advice and support. It is also possible to get additional funding from the European Union.

2.10 Decision making

Theory of decision making and especially its applied form called decision analysis was invented for the decision making support for decision problems in under uncertainty and risk. Decision making in business enterprises is closely related to successful operation of the whole organization. If wrong decisions are made business enterprise does not operate efficiently, loses its customers, market share and cannot organize the manufacturing process so costs of production cannot be decreased. Risk management allows decision makers to identify individual risks and then to manage these risks by implementing steps which decrease the risks or completely eliminate the identified risks (Byrne, 1996). Decision makers can use several tools to support their decision making process by hiring external advisers, using specialized decision support software or rely on external services and databases to facilitate the collection and analysis of relevant information.

Information plays a very important role in the decision making process. There are three different things related to information in the decision making process - information, data and knowledge (Nutt & Wilson, 2010). Information can be defined for example as data that are in a context and carry a meaning which is understood by humans. Or information can be defined as each message that gives new knowledge to the recipient of the message. Information is also defined as a message that reduces the uncertainty. Data on the other hand can be defined as organized information collected for a specific purpose. Knowledge can be defined as clear and confirmed imagination of something, practical experience or skill. In decision making knowledge is information that was organized and analyzed so that it is clear and understandable and can be used for solving problems, decision making or learning. There is a hierarchy of these three terms. Knowledge is a subset of information and information is a subset of data.

Basically there is unimaginable amount of data in the real world, very small subset of the data is information that is useful to one person for some decision problem and from this information very little information is actually useful knowledge for the decision maker. There is also an interesting relation between the amount of information and its usefulness and efficiency of its use (Grünig & Kühn, 2009). If there is too little information collected its use is not efficient, when there is almost all information collected it took too much time to collect this information and usefulness of individual information decreases. The efficiency of use of single information is somewhere between minimum and maximum of collected information. With enough information collected the interrelationships between individual information can be found to understand the dependencies and rules. In ideal case with unlimited time and unlimited access to information it is of course ideal to collect and analyze all available information. But in the real world there are too many questions to answer and too little time so the decision makers have to intentionally omit some details in order to progress faster with their decision making process.

Decision tree is a decision support tool that uses a tree-like model or graph. This tree records the decisions and possible consequences including random events that can happen, costs of resources etc. Decision trees are frequently used in many scientific areas including operations research and decision analysis (Mullen & Roth, 1990). They are used to identify strategies that are most likely to reach desired objectives. Another use of decision trees is to calculate the conditional probabilities. Decision tree has three types of nodes - decision nodes which are commonly represented as squares and the chance nodes that are represented by circles, end nodes are represented by triangles. Decision trees have several advantages - they are easy to understand and interpret. They also give a good description of the decision problem even if there is little data available. Decision trees can be also combined with other decision techniques. Decision making process can be divided into three separate phases. First phase is analysis of the environment - this phase includes the analysis of terms which cause the need to make a decision, identification of decision problems and finding out what caused the decision problems. Next phase is devising the solution in this phase the decision makers consider the analysis of present situation and think about the possible future development while different solutions are implemented.

Control phase follows the implementation of the decision. Close observation of how decision makers access the decision problems brought many interesting facts for example - decision maker's attitude is influenced significantly by his previous experience with similar decision problems - several decision makers with different backgrounds access the same decision problem differently - they always search for experience that is relevant and helps to find successful solution based on the information that is known to the decision maker. When there is a need to collect information the decision makers tend to collect information they understand while omitting the information they do not understand. This interesting finding is caused by the time required to make the decision.

If the decision maker does not understand some information it is probable that he or she will need some time for studying this new unknown information and it will prolong the decision making process. Should the decision problem be connected with a lot of unknown information the decision maker does not spend long periods of time for studying the unknown information but instead the decision maker only uses the known information and makes the decision based on this limited information. Third interesting observation is that the decision makers tend to look for and collect the information that is supporting their opinions and the solution they will offer as a result of their decision making process. They also tend to find argumentation against the information that is against the solution they are formulating for decision problem.

Should an important decision be made it is always important to consider these observations which are related to human psychology. When there is a team of independent decision makers instead of one - there is a high probability that each individual decision maker will devise a unique solution to the decision problem by finding and selecting unique set of relevant information which influenced the individual decision maker before he or she found the solution. Decision process has several basic elements including the objective of decision making. In business enterprise the objective of a decision making process is the desired state of the company and its environment in the future. The objectives can have verbal or numeric formulation. Either way the objectives have to be formulated so that it is easy to control and measure the progress made towards the objective.

Decision criterion is also important thing to consider because the objective can be either to increase the profits or reduce the costs - decision criterion can be qualitative or quantitative. Quantitative criterion has a clear advantage that it can be measured precisely. But it is the qualitative criterion that is found more often in the decision making processes in business enterprises. It is also important to divide subject and object of the decision problem. Subject is either one decision maker or a team whose task is to find a solution for a decision problem. The object is the business company in which the decision problem is solved. Next very important things are the alternative solutions. In simple clearly defined decision problems all alternative solutions are known. In complex decision problems the alternative solutions are not known and have to be discovered by processing the relevant information. There is a rule - the more relevant information the more complex the decision problem. Large amount of relevant information signalizes that there are many variables that influence the decision problem and the more variables and factors there are the more alternative solutions can be found.

Decision problems can be divided into several categories. They can be divided between static and dynamic decision problems - this is influenced by the time duration of the decision problem. Next they can be divided into single criterion and multiple criteria decision problem. Management in business enterprises divides them into operative, tactical and strategic decision problems - the strategic have the longest duration and have the most significant impact on the operation of the business enterprise in the future. They can be also divided into two categories considering if there is an opponent or competitor. Next the decision problems can be solved by one individual decision maker or a team of decision makers - decision problems solved by a team of decision makers have many specifics and are itself worth of further research - psychology of the individual decision makers and their roles play a key role in the whole decision making process. Decision problems can be also capable of being programmed (described by an algorithm in computer language) or they cannot be transformed into computer language and there is no single algorithm that finds the solution. By their complexity they are divided to well structured and poorly structured.

Usually the strategic decision problems of business companies are very important, have long-term impacts, are poorly structured and have many factors and criteria influencing them. Risk plays a very important part in decision making (Byrne, 1996). Risk can be defined as the deviation of one or more results of one or more future events from their expected value. Another definition is the variability of possible outcomes and the uncertainty of achieving them. Or it can be defined as deviation between real and expected outcomes. It is also a probability of result that is different from expected result. Deciding a problem in conditions of uncertainty is much more difficult than to decide the same problem if all the relevant information and the alternative solutions are known.

In some cases the solution can be devised by applying previous experience with similar decision problem by analogy. There are several different methods to handle risk in decision making. One is to estimate the highest possible earnings in the worst possible scenario - this gives the decision maker the idea about what to expect should the worst possible scenario happen. It would be shortsighted to expect only the best possible scenario. Another useful method is to average the optimistic and pessimistic scenarios - such average should not too distant from the actual situation in the future. Another method to minimize risk is to choose the path leading to smallest possible loses.

Decision making under uncertainty is far more difficult than decision making in scenario where all acquired information is correct and known. Especially on the market and in social sciences in general uncertainty is encountered very frequently. It is due to the fact that the behavior of consumers is hard to define. It is possible to make quite precise measurements based on the careful observation of the reality but it is very hard to predict the future behavior of the consumers or the future development of the market price of some property. The more dynamic the market and the more long-term the prediction should be the less accurate it is. There are several main issues when working in an environment which has unknown or uncertain factors and conditions. If some information is unknown it is usually possible to estimate the approximate value of this unknown variable.

Qualified guess often helps decision makers to overcome the uncertainty caused by a small number of important parameters of some investment alternative that are not known to decision makers. It is far more difficult to solve this problem in a dynamic environment. As the decision making process takes time – the more complex decision the more time it takes to make the decision. During this time the accuracy of the information gathered initially deteriorates.

Several methods can be used to deal with the uncertainty. There are well known basic methods based on statistics, probability, decision theory and theory of utility. It is useful to always have a clear hierarchy in what information is useful and important and what information is less useful and not so important (Bhushan & Rai, 2004). If all important information is correct and available and few not so important factors and parameters are not known it is easy to make the optimal decision. But considering a scenario where the several most important parameters are not known and difficult to estimate but all the insignificant details are available – to make optimal decision in such conditions is far more difficult and takes significantly more work and experience than in the first theoretical example.

Another method is to trade time and resources for certainty – most unknown parameters can be observed, measured or carefully estimated so they are not known precisely but at least the estimation gives much better idea about the property than when no time and resources is spent and the parameter is just unknown. General rule is: if something is very important it is a wise investment of time and money to carefully estimate the possible value of an unknown parameter. Uncertain information of different kinds can be fused together. It is easier to evaluate a dynamic system after observing a similar dynamic system in comparable conditions. Modeling and simulation can be used to simplify the complex reality and simulate the possible future development of target parameter. It is very important to structure complex problems so the understanding of the problem is optimal. Real estate investment plays an important role in most business companies. The positive impacts of well timed expansion of manufacturing capacity can provide a head start that is crucial on today's dynamic market with strong competition.

Before analyzing the possible alternative investments it is important to carefully analyze the needs and motives inside the company. Large investments are advisable for strong companies. Small company that has little spare resources has to thoroughly analyze all possible scenarios as large investment can make the company vulnerable. When thinking about real estate investment it is necessary to realize that price and value are not the same. It is good to invest when the price of a property is lower than its market value. Investment value should be always higher than the price. It is also very important to think well ahead into the future – what are the positive but also negative possible scenarios.

It is more difficult to make decisions in an environment with unknown parameters and information. If some information is unknown and it is very important it is a wise investment of time and resources to carefully estimate the possible value of this unknown parameter. Uncertain information of different kinds can be fused together. Making decisions and predictions in a static system is easier than operating in a dynamic environment. It is easier to evaluate a dynamic system after observing a similar dynamic system in comparable conditions. Modeling and simulation can be used to simplify the complex reality and simulate the possible future development of target parameter. Modern methods of soft computing can be used for creation of such models. It is very important to structure complex problems so the understanding of the problem is optimal.

2.11 Multiple-criteria decision analysis

Multiple-criteria analysis often shortened as MCA is a decision-making tool developed for complex problems with a multiple relevant parameters (Nijkamp & Spronk, 1981). Situations where multiple criteria are involved can lead to confusion and incorrect decisions. For example some decision makers may think that some parameters are more important than others. This may be caused by their bias toward certain area or expertise. To eliminate bias of a certain individual it is better when a team of decision makers makes the decision. Another fact to consider is when there is a team of people making the decision they can disagree and reaching a consensus can be impossible or very difficult to achieve. MCA is a complex approach which is applied in many different areas where decision makers face various challenges caused by the combination of complex problems, large amount of information, multiple objectives and other factors (Figueira et al., 2005).

The traditional framework for analyzing decision making presupposes the existence of three elements: a decision maker (single decision maker or a group of decision makers recognized as a single entity); an array of feasible choices; and, a well-defined criterion of choice such as utility or profit. The given criterion is then used to associate a number with each alternative so that the feasible set can be ranked, or ordered, to find the optimal value that is attainable for criterion of choice (Romero & Rehman, 1989). It is very important to first consider the general concepts and then delve into more specific applications of multiple criteria analysis. To successfully implement MCA means to use methods such as ranking, rating and pairwise comparisons in the analytic hierarchy process also known as AHP. It is necessary to follow a logical, well-structured decision-making process. Another important thing is the context. The context can be both from a top-down perspective as well as bottom-up. Decision makers skilled in the use of multiple criteria decision analysis can solve most problems they encounter. MCA is therefore very important for business companies as the amount of information, variables and inter-dependencies steadily grows. Commercial enterprises on the market face stronger and stronger pressure from their competitors. It is essential for a successful business to use all available resources efficiently. Companies use many different methods to decrease costs and maintain their profit.

This dissertation discusses another very important decision making process - the decisions related to real estate investment. Before the decision is made it is necessary to thoroughly analyze all relevant parameters. Managers often face this uneasy task under pressure from their superiors and they often have too little time to make the decision. To decide which real estate is the most suitable for the particular business enterprise requires to define a set of relevant parameters. The decisions related to real estate investments are strategic decisions as they are long-term. Incorrect or suboptimal decision can lead to the loss of competitive advantage. It is easy to decide when there are few alternatives and few relevant parameters. Another case when it is easy to make the decision is if the decision can be reversed or has insignificant impact on the business.

If there are many alternative solutions it is more difficult to decide. Existence of multiple relevant parameters which are difficult to quantify and influence the decision makes the decision problem even harder (Munda, 1995). Especially if the future development and plans have to be taken into consideration. The most difficult case is when there are many alternatives, large set of relevant parameters, many requirements, large team of people that influence the decision making process and short time to make the decision. Most managers will probably agree that this is exactly the case with the most important decisions that influence the business units they are leading. Responsible decision makers always consider worst case scenarios and decide after they have analyzed these scenarios. Every decision related to real estate has to be preceded by thorough analysis of financial situation of a business enterprise.

Multiple criteria decision analysis tells managers to focus on analysis first. This analysis of current situation, goals, constraints, parameters and possible consequences can take a long time and a lot of work has to be done. After initial analysis the decision maker has to set relevant parameters. After this step the relevant data have to be collected and analyzed. The reliability of collected information can vary. Some information can be precise and some collected data can be based on qualified guesses - therefore can be less precise and can negatively influence the resulting decision based on this information.

After enough relevant data is collected and analyzed the parameters are evaluated and ranked by their influence. MCA tells the decision maker to make a list of criteria ordered by their relative importance and then to evaluate these criteria (Mendoza & Macoun, 1999). This step is followed by analysis of all possible scenarios including the best and worst case scenarios. Then it takes to compare these scenarios with the long-term strategic goals of the company. If the resulting state is acceptable by the decision makers and there are conditions for achieving this resulting state the decision is made. After the decision has been made it is necessary to allocate required resources. It is important to be careful with evaluation of availability of resources. Conditions and the environment can change and it may become difficult or more expensive to get the resources in the future. For example a loan may become more expensive and if there is only a small profit margin the whole operation can result in losses that can cause serious problems to whole business.

Once the decision has been made it is time to plan all activities needed to achieve the set goals. This plan has to include reserves for the case that some unexpected obstacles occur. Good manager also checks frequently to see if milestones are being met ahead of schedule to avoid delays and losses**.** Multiple criteria decision analysis offers ways to avoid making mistakes in situations when other decision making methods are likely to lead to incorrect decisions. If manager decides without careful analysis of conditions he is most likely to make a mistake that costs time and resources.

Wrong decisions are always bad news for a business enterprise. Managers in charge must do everything they can to avoid wrong decisions. It is necessary to always gather enough information so that no important aspects are overlooked. To analyze the information, evaluate and rank the parameters always takes time. Therefore decision makers have to work efficiently so they do not spend a lot of time on the less significant details and steps. General recommendation is to plan in advance. It is important to have enough time to collect enough information. The information has then to be analyzed. This requires some time depending on the scale of the decision that is being made. After enough information is collected and analyzed it is necessary to think about the parameters.

Some of the parameters will be very important and other parameters will be insignificant. Therefore a set of relevant parameters has to be found. These parameters then have to be ordered by their relative importance for the decision. Then it is necessary to think about all possible decisions. Once all decisions are known the list of resulting scenarios is evaluated. All available information is then thoroughly analyzed and decision is made. Decision makers have to be careful at all times in order to avoid situations where a small mistake in the process can lead to a wrong decision. Especially when the decisions about real estate investment are made it can lead to problems as these long-term investments require a significant amount of resources.

2.12 Soft computing

Soft computing is a relatively new term that is related to information technology and artificial intelligence, it became a formal computer science area of study in the early 1990's according to (Zadeh, 1994). It is characterized by the use of inexact solutions to computationally-hard tasks which solutions cannot be found in polynomial time (Jain, 2008). Soft computing includes fuzzy logic, neural networks, evolutionary computing, chaos theory and several other areas. Soft computing is often used in economics due to the nature of vague information and complex relationships that can be found in economics more frequently than in other research areas (Aliev et al., 2004). This research is related to soft computing because it uses fuzzy logic and several methods commonly used in soft computing will be used during the collection of data and other activities that will be necessary in order to accomplish the research goals.

Genetic algorithms are special heuristic search algorithms that behave similarly to natural evolution. Genetic algorithms are often used in optimization and search problems and are inspired by the famous theories of Charles Darwin and Gregor Mendel. Basic idea in evolution and in genetic algorithms (GAs) is the survival of the fittest - strongest individuals survive while the weakest perish. GAs have applications in fields like bioinformatics, computational science, engineering, chemistry, economics, mathematics, physics, logistics or manufacturing (Hoffmann et al., 2005). Commonly used terms in this field of study are inheritance, mutation, selection and crossover.

These are the basic processes that are also important in the natural evolution. Interesting trait of GAs is that they are able to solve different types of problems regardless of the character of the problem or the data or relationships between the variables. If new conditions and limitations are added it does not lead to more complicated algorithms and descriptions like for example in mathematics - more complex problem leads to more complex process to find the solution. Some problems that cannot be solved by other methods can be solved by GAs in a very short time. Genetic algorithm has several phases. In initialization phase the set of large number of individual solutions is randomly generated to form the initial population. The initial population can have several hundred or several thousand possible solutions. Usually this population is generated randomly and should cover the entire range of possible solutions - this is called the search space.

In selection phase the current existing population is evaluated by the fitness function and the fittest solutions are selected to breed a new generation of solutions. In the selection phase a small number of less fit solutions are selected in a stochastic manner in order to keep large diversity of the population. For this selection the tournament selection or the roulette wheel selection are frequently used. In the next phase called reproduction the selected solutions make a second generation of solutions. Two basic operations occur at this time - crossover which can also be called recombination or mutation. Each new solution produced has a pair of parents. This process ensures that the solutions in the next generation are different from the previous generation and new solutions occur.

Some researchers claim that better results are achieved by using not just two parents but three or more. Better solutions can be found in fewer generations - one disadvantage of this approach is that the computation required in the phase of reproduction can take longer time. The generational process is repeated until the termination conditions have been reached. In the termination phase the termination conditions are tested. Termination condition can be for example - a solution is found that satisfies set criteria. Or a set number of generations were generated. Or allocated time has passed or the required resources have been spent.

Another termination condition is that the best solutions are not improving in following generations and there is decreasing probability to find better solutions that those that have been already found in current generation. GAs have certain advantages but also several disadvantages - one of these is that the required amount of time and computation is often high as thousands of different evaluations and conditions have to be computed. Also GAs often tend to find local optima - after certain number of generations local optimum is found and is outputted as the optimal solution for the whole problem - but some conditions may influence that the real optimum is not found (Cao et al., 2010). Also it is difficult to apply GAs to dynamic problems where input data evolves with time - the data set inside the individual solutions changes and during the computation this data becomes inaccurate and does not truthfully reflect reality of the source problem.

There are several other related techniques similar to the concepts of genetic algorithms. For example: ant colony optimization, evolutionary programming, extremal optimization, random search, gaussian adaptation, genetic programming, harmony search, memetic algorithm, simulated annealing or stochastic optimization. The application of genetic algorithms offers promising results in this research. But GAs alone cannot solve the whole research problem. Genetic algorithms may be used to find investment alternatives that match the requirements of the investors. A possible problem is that the requirements have to be specified accurately. Fuzzy logic showed more promising results when dealing with vague input information and vague requirements. Genetic algorithm toolbox in MATLAB is shown on the following figure.

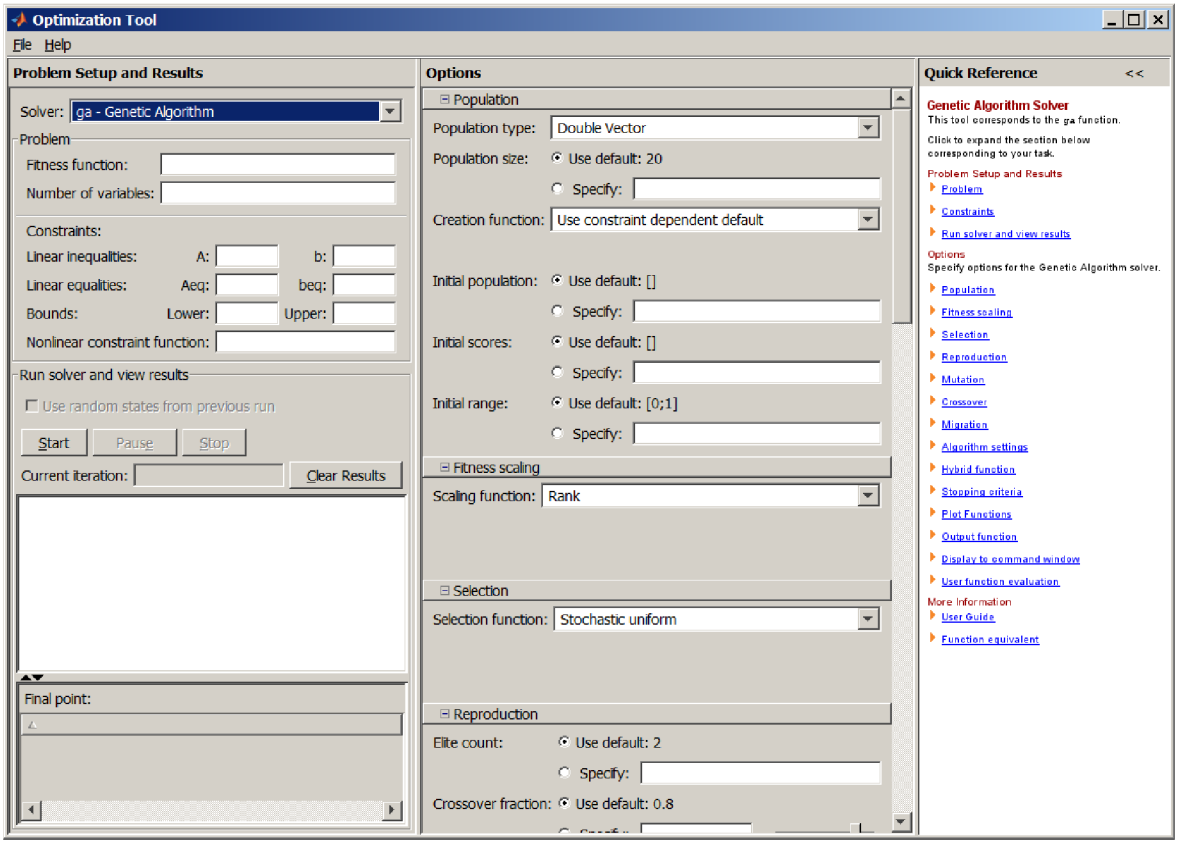

Figure 1: Genetic algorithm toolbox in MATLAB (Source: MATLAB)

Neural networks and the related field of study examine artificial neural networks which simulate biological neural networks (Fortuna et al., 2001). Artificial neural networks can be used to solve wide variety of problems. Especially problems that are difficult to program in common programming languages or some complex tasks can be solved easily by artificial neural networks (ANN). ANN basically contains large number of software neurons which are programmed so they mimic the behavior of biological neurons. Artificial neural network is then executed to analyze special set of input data which allows the ANN to learn and find relations and patterns in the input data. Making the training set of data is not easy and there are special requirements on the information the data set should contain and the ANN should learn from the input data. Once the ANN learns it is then able to process the actual input data with the rules and knowledge it learned from the training set. The process of learning the artificial neural network requires numerous iterations in which the weights of individual relations between neurons are set and it is calculated how this change influenced the resulting behavior (Rutkowski & Kacprzyk, 2003).

Complex decision problems require more complex artificial neural networks that consist of several layers of neurons. Major drawback of this is that the complexity of the neural network increases dramatically and at a certain point the ANN may become too complex so it stops being efficient or starts to output incorrect results, or cannot learn. Artificial neural networks are used frequently in regression analysis, function approximation, time series prediction and modeling. For example the use in time series prediction is based on the expectation that there exist some unknown relations and patterns in how the time series behaves during a specified time period.

Neural network tries to learn from the time series and repeating and significant events from this time series are recorded into the artificial neural network which can then with some degree of probability predict the future development - should the ANN prove to be successful in this prediction - for example if it can predict the future development with probability higher than for example sixty percent can the artificial neural network be used as a tool to predict the future development - at least until the character of the time series changes or some factors which caused the certain behavior recognized by the ANN change. Next important use of ANNs is for classification and especially for sequence and pattern recognition. It can also be used for decision making systems that have sequences of dependent decisions.

Another useful application is in data processing, filtering, clustering and compression. One of the advantages of ANNs is that it helps to find regularity, patterns and sequences in seemingly random data. When compared to other methods ANNs can solve some problems in much shorter time than other methods - but some problems cannot be solved at all with artificial neural networks or it is too complicated to apply ANNs for the solution of these problems. When some new and unknown problem is researched it is good to think about possible application of various different methods which could help to find the solution - to solve all problems with just one method is very inefficient - research in many different areas showed that there is not such single method that can solve all problems efficiently.

ANNs have some disadvantages that are unique when compared with other methods. For example when artificial neural network is learning and there is a series of some events that does not change very often - ANN expects this event to occur in the future and behaves incorrectly when some infrequent event happens. This problem is caused by mistakes in the training set. Another problem is also the over-training of the ANN - after some time the training of ANN is not improving the ANN. Artificial neural networks also look very promising because they mimic the behavior of human decision maker and the analysis of input data with ANNs can be used in the future for comparison with the researched method based on fuzzy logic and clustering which is proposed in this work. Following figure shows the neural network toolbox in MATLAB.

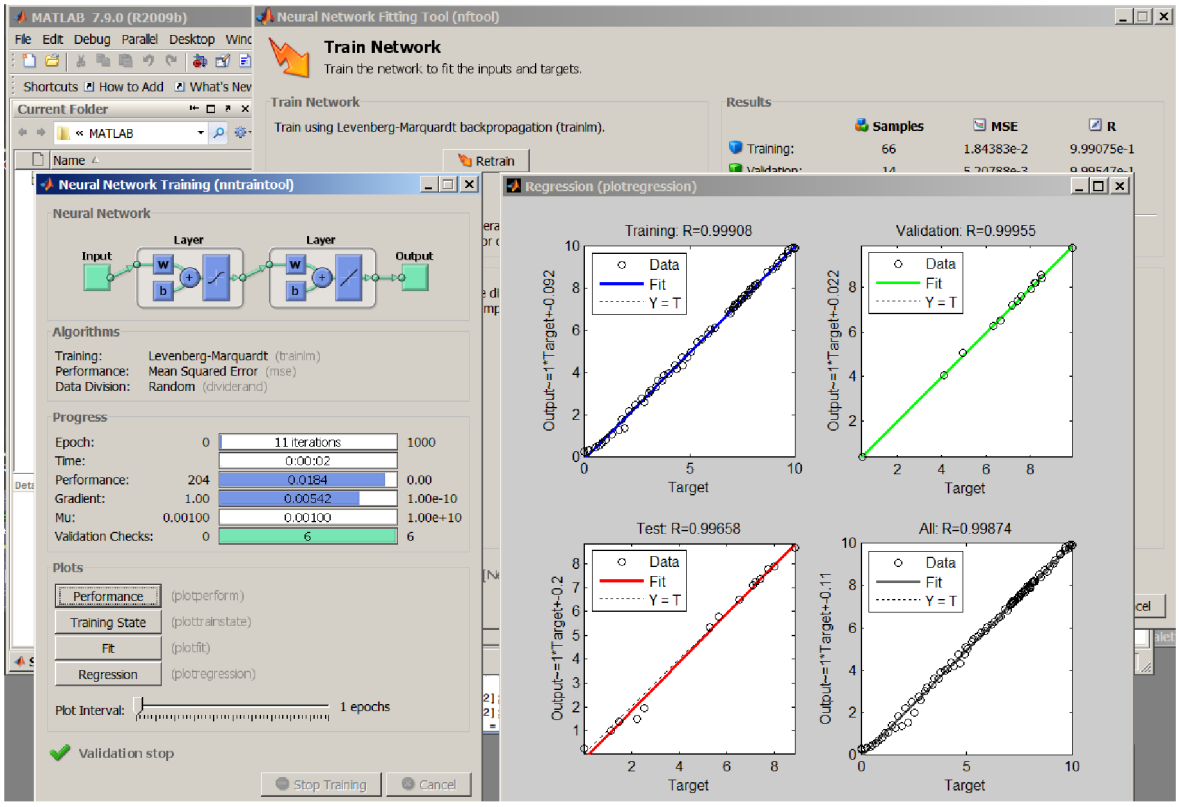

Figure 2: Neural network toolbox in MATLAB (Source: MATLAB)

2.13 Fuzzy logic

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Fuzzy logic is derived from the fuzzy sets initially researched by Lotfi A. Zadeh in 1965. In contrast with binary sets having binary logic, also known as crisp logic, the fuzzy logic variables may have a membership value of not only 0 or 1 (Klir & Yuan, 1995). Just as in fuzzy set theory with fuzzy logic the set membership values can range (inclusively) between 0 and 1, in fuzzy logic the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values {true (1), false (0)} as in classic propositional logic (Novák et al., 1999). Fuzzy logic uses linguistic variables and dictionaries of these variables. Work with variables is slightly more complex because of the additional operations required by fuzzy logic. But this additional effort awards the decision maker by answers to questions that cannot be answered by other methods. There are only few conditions that the problem has to meet so fuzzy logic can be used to solve this problem. Human behavior cannot be precisely quantified and so it is easy to work with it with word variables like for example small preference, medium preference, high preference of various products. The membership function can be described graphically by using curves. These curves have shapes similar to the letters "S", "Z", "λ" and "π". The membership functions are applied not only to the input variables but also to the output variables.

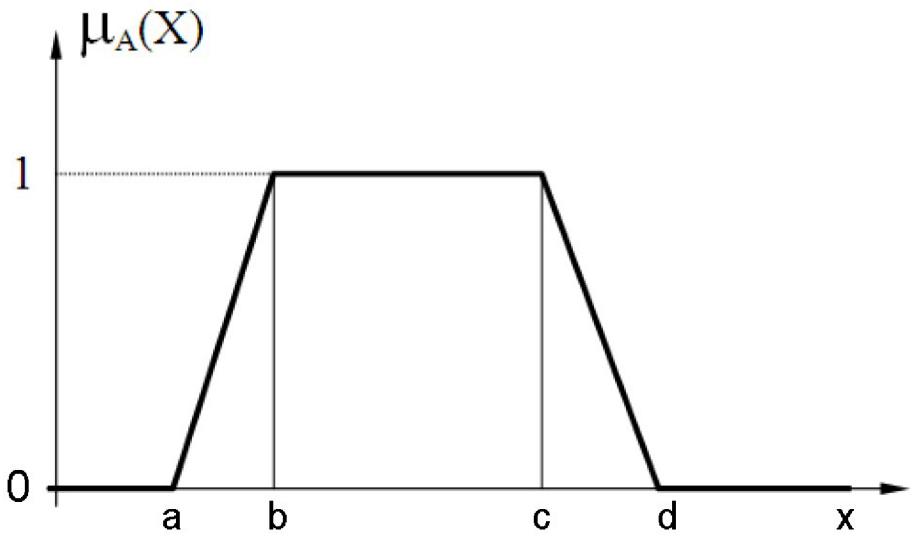

Figure 3: Grade of membership in a fuzzy set (Source: Own work)

There are several different grades of membership determined by points a, b, c and d:

$a = b = c = d$	(precise numeric value)
$a = b, b < c, c = d$	(interval of uncertainty)
$a < b < c < d$	(trapezoidal fuzzy set)
$a < b = c < d$	(triangular fuzzy set)
$a = b = -\infty, c = d = \infty$	(unknown information)

Values outside of the interval (a; d) have a grade of membership equal to zero:

$$\mu_M(-\infty; a) \wedge (d; \infty) = 0$$

Values in the interval (b; c) have a grade of membership equal to one:

$$\mu_M(b; c) = 1$$

Values in intervals (a; b) and (c; d) belong to the fuzzy set only partially:

$$0 < \mu_M < 1$$

Fuzzy expert system consists of a set of conditional statements.

	X_1	X_2	X_n	Y
1	A_{11}	A_{12}...	A_{1n}	B_1
2	A_{21}	A_{22}...	A_{2n}	B_2
3	A_{31}	A_{32}...	A_{3n}	B_3
.....				
m	A_{m1}	A_{m2}	A_{mn}	B_m

Figure 4: Fuzzy expert system (Source: Own work)

Fuzzy computation is divided into three steps. First step is the fuzzification - in this phase of the computation the real input values are transformed to the linguistic variables used in the fuzzy model. Usually there are several linguistic variables assigned - between three and ten. Next step is the fuzzy inference - this step is the essence of fuzzy logic. The behavior of the system is described by rules if, and, or, then. The behavior of the system is recorded by the combination of the linguistic variables and these rules - each individual combination is called statement. One statement is the description of certain situation. The set of all statements describes the behavior of the system that is being simulated with the fuzzy model. The set of all statements is called a knowledge base.

Thanks to its nature the fuzzy model can be understood as a fuzzy expert system and is a valuable decision making support tool. Each statement can have a different weight which is determined by the person designing the fuzzy model. Statements can but usually do not have same weight - some statements are more important than others. Last step is the defuzzyfication - in this step are the results of fuzzy inference transformed to real values. In order to simulate some system with fuzzy logic - several input and output variables are required. The fuzzy model requires intensive computation. The fuzzy model therefore has to be programmed in a special fuzzy logic software, fuzzy toolbox of Matlab software, Fuzzytech or in other fuzzy logic software like for example FuzzyCLIPS.

Economics is an ideal field for the application of fuzzy logic as it has many variables that are difficult to quantify (Buckley et al., 2002). Decision makers often have to use qualified guesses so that they are able to make decisions that require information that is not available. Qualified guess substitutes very expensive research that would have to be done to get the precise input data. Fuzzy logic is a form of logic derived from theory of fuzzy sets. It is a tool that helps with the reasoning when input variable are not precise or "fuzzy". In binary logic the variables are or aren't members of a certain set in fuzzy logic variables can be members of a set to a certain degree. This degree can be anything from zero to one. Fuzzy logic uses linguistic variables and dictionaries of these variables. Work with variables is slightly more complex because of the additional operations required by fuzzy logic. But this additional effort awards the decision maker with answers to questions

that cannot be found with other methods. The use of fuzzy logic requires additional work and the decision maker only gets correct results when all steps he does are made without error. Incorrect claims and incorrect input data will produce misleading results. It is necessary to input only relevant data and variables.

Translated input variables are entered into the model along with the input statements. The process of fuzzy inference produces results which then need to be evaluated. Interpretation of these results requires a certain degree of experience (McNeill & Martin, 1994). It is possible to use basic methods of fuzzy logic without the fuzzy logic software. However to gain most from fuzzy logic it is necessary to create a complex model and use the fuzzy logic software. Fuzzy logic provides very versatile methods and tools that can be used to solve many different problems. Human behavior cannot be precisely quantified and so it is easy to work with it using non-numeric variables like for example small preference, medium preference, high preference (of a certain product for example). Fuzzy logic is a very useful tool that can help researchers, investors and managers to analyze and evaluate various situations that are influenced by factors that cannot be easily quantified.

There are various software products that facilitate the use of fuzzy logic. It is necessary to collect enough information and determine which variables will be used. Fuzzy logic enables decision makers to analyze complex situations and solve complex problems. This is a clear advantage of fuzzy logic. There are also several disadvantages. One of the disadvantages is the complexity of the process. It takes certain amount of time to collect enough information, process the information, create the statements, create the model and in the final phase it takes effort to interpret the calculated results. However the time spent on preparing the information returns as the ability to solve complex problems which are difficult to solve with other methods and approaches. Fuzzy logic has proven to be very useful for solving economical problems due to the nature of these problems and the character of the factors and variables that influence them. Sophisticated software is also available which makes the work with fuzzy variables and with the model much easier.

2.14 Data mining

Data mining is can be described as a process of extracting patterns from data (Chakrabarti & Cox, 2009). Data mining can be used in many areas for example in engineering, surveillance and other areas. In business intelligence data mining can be used to gain informational advantage. Discovering unknown relations and patterns in known data has strategic importance for business companies and decision makers. The research problem is closely related to data collection and analysis therefore data mining and its algorithms are used in certain phases of the research. Data sets have grown in size and complexity. In order to keep up with the growing amount of available information modern and powerful methods of data collection and analysis have to be used to support decision making (Han et al., 2012). Manual extraction of patterns from data has been used for a very long time but during last two decades the process of pattern extraction was automated with the help of newest computer hardware and sophisticated data mining algorithms (Lin et al., 2008). Data mining is used frequently in profiling, fraud detection or surveillance.

Any new useful information that can be obtained from the existing historical records in a business company is valuable - especially when it can be used to gain new customers or optimize existing processes. Another very important objective of all businesses is to reduce costs. Data mining provides new valuable information about important data in short time. Without data mining the new information can be discovered randomly after longer period of time or it can remain unknown when no one discovers it (Abbass et al., 2002). Data mining can also be used to find new relationships between variables in a dynamic environment (Hand et al., 2001). The world markets become increasingly unpredictable and any help decision makers can get when they formulate the strategic objectives - for example related to real estate investment - is very valuable. New previously unknown interrelations can be found from data logs which observe the behavior of certain subjects, especially when the behavior cannot be described by logical rules or predicted. In order to use data mining a large enough record of data has to be collected and processed. It is possible to use data mining software to simplify the data mining process.

Data mining software often contains powerful methods and algorithms which make it easier for users to find hidden patterns and interrelations in the collected data. Several tasks are frequently used in data mining. One of these tasks is clustering. Clustering helps to discover new groups of elements and patterns in the input data. There is a high probability that data collected in the past contains unknown information that can be valuable. Only thing required is to invest some time and resources for data mining. Second common task used in data mining is classification. It is a process of generalization of rules which can then be applied for new unknown data. It is then easier to work with a new unknown entity when it is classified as being similar to a group of known entities.

It is then possible to predict its behavior and parameters based on existing knowledge of other entities in the group. Discovering such similarities makes decision making easier and reduces uncertainty and amount of unknown variables in a dynamic system. Common algorithms used in classification include neural networks, nearest neighbor method, decision tree learning or naive Bayesian classification. Next commonly used task in data mining is regression. The objective of regression is to find a mathematical function which describes the data. The discovered function is not precise but it helps to predict the behavior of a dynamic system with probability which can be calculated. Fourth class of tasks is the association rule learning - it finds the associations and relations between certain entities in the input data. It is used frequently for example in marketing to determine the types of products the customers purchase together. The use of neural networks in data mining means that in some cases the data mining algorithms can learn from the training sets of data - this process of learning improves the accuracy of the algorithm when it is used on the input data.

Like the other methods used in soft computing the results gained with the help of data mining are not precise but even so they can positively influence the decision making process or help to predict the behavior of a complex system. In business data mining is used frequently in customer relationship management. Customers can be targeted with the help of available information about their behavior and habits. Targeting customers can significantly reduce the resources that have to be invested into getting new customers.

The research problem requires the analysis of large amount of data. The ideal investment opportunity can be seen like it is hidden among the other investment opportunities. Only way to find the ideal investment opportunity is to have a well described and understood set of requirements - these requirements have to be formulated by the investor - the more specific needs the investor has the better specification of the requirements has to be provided by the investor. Another thing to consider is that the input data can be unknown or incorrect. The designed decision making support system has to be robust enough to come to terms with this. Data mining itself is not powerful enough to solve the research problem alone. A combination of several approaches has to be researched and used to make a flexible and robust system which helps the decision makers to reduce the set of possible investment alternatives based on their specific needs and future strategic objectives and plans.

2.15 Cluster analysis

Clustering or cluster analysis is a method of assigning a set of entities or observations into one cluster (Romesburg, 2004). Clustering is very useful in many areas especially when there are large sets of individual entries. It is easier to work with several clusters of similar entities instead of working with each entity separately. Cluster analysis is frequently used method in statistical data analysis, data mining, pattern recognition and other sciences including for example bioinformatics. New area where clustering is used is the analysis of social networks which emerged recently on the Internet. Another very important application of clustering is in marketing research - customers can be clustered based on their preferences or their behavior. In a dynamic environment with many factors influencing decisions it is very complex to predict or describe the behavior of individual elements. Especially in marketing where each individual customer has different needs, opinions and experience. Analyzing customer behavior and clustering customers proves to be very useful and opens new possibilities. Clustering is also frequently used in sociology, education research and other areas which focus on the behavior of people.

Clustering has several main advantages - it is a good way for quick review of whole set of entities. Person analyzing the input data has to analyze only a set of several clusters of similar entities which consumes much less time than to review each individual entity in the set of input data. Each cluster can be well described so it is possible to assign new elements based on their characteristics - once the clusters are identified work with the input data becomes much easier and more efficient (Everitt et al., 2011). One of disadvantages of clustering is that one entity can be assigned only into one cluster - should the system of clusters be simple this rule has to be applied. Some entities can be more or less similar to other entities and the membership in a certain cluster is not same for all entities in a single cluster. Also in some algorithms the resulting clusters can be influenced in the initial phase of clustering by the choice of centers of clusters.

There are several types of clustering (Höppner, 1999). Hierarchical clustering creates several clusters which are organized into a hierarchy. This hierarchy can be described by a tree structure. Initial node - root of the tree - is a set containing all elements in a cluster. Another type is the conceptual clustering. Unlike data clustering in conceptual clustering the description language and regularity are important factors. Partitional clustering uses k-means clustering algorithm or fuzzy c-means clustering algorithm. The fuzzy c-means clustering algorithm is very interesting from the point of view of this research because each element has a degree measuring how it belongs to a certain cluster (Uprichard & Byrne, 2012). Elements that are in the center of a cluster belong to the cluster more than those elements that are near the edge of a cluster. Another type is QT clustering - this type is an alternative method for partitioning data and it was developed specially for genetic clustering. Next type - the spectral clustering which uses similarity matrix the mathematical calculations used in this type of clustering use eigenvectors, eigenvalues of the Laplacian matrix. Important step in the clustering algorithm is the distance measurement. This step uses mathematical equation to determine the distance between two elements - this distance can be understood as the measure of similarity. Elements that are similar can be then assigned into a single cluster.

2.16 Availability of required resources

Several resources were required in order to achieve the set research goals. This paragraph contains a list of these necessary resources. If any of these resources was unavailable then it would be difficult to reach the set goals.

- Availability of input data for testing.
- Availability of specialized software – proprietary fuzzy logic software, MATLAB.
- Graph drawing software, Java programming language, data collection software, data processing software.
- Case studies for evaluation and comparison.
- Possibility of consultation with real estate investors.

3 Solving the research problem

3.1 Prerequisites for using this research

This research is intended for investors who are planning to purchase and redevelop brownfields. The objective of this research is to provide a decision making support method for the investors. The proposed investment evaluation method is particularly useful in scenarios where the investor chooses from a large group of investment alternatives. For example if there is more than one hundred investment alternatives. This method allows the investor to carefully analyze and compare the individual brownfields based on the hierarchy of parameters describing the brownfields. The application of similar approach based on the hierarchy of parameters was researched in (Kučerová, 2006). This research has several requirements. The most important requirement is that the investor has clear objectives and has to be able to clearly define own needs. Only then can the new method output valid recommendations that reflect the needs and objectives of the investor. If the objectives and needs are rational, logical and well defined then this new decision support method can be used. The set of parameters is defined by the investor according to the needs and objectives the investor has. Every investor has different needs so different sets of criteria will be used for each investor. In order to test the fuzzy model a set of general criteria was defined. These general criteria should be useful for most investors. The creation of this set of general criteria allowed to extensively test the model for different scenarios and different input data. There are also several other prerequisites. For example enough information about the investment alternatives has to be available. The decision about which brownfield should be chosen for redevelopment is very complex. Each brownfield is described by for example two dozen criteria. The objective of this research is to make a reliable decision making support so the recommendations the model outputs have to be correct. Even if fuzzy logic is able to work with several unknown criteria – the more unknown criteria there are for a single brownfield the less accurate the recommendation will be. One way to solve this is to estimate the unknown information. The initial phase of the process – the data collection and processing is very important. The more information is collected the more precise the recommendations will be.

Some information about the brownfield site is always available – for example the price, area, equipment, infrastructure etc. But some information is usually not known, for example the true level of contamination. Previous owners of the brownfield often do not provide this information. It is necessary to be prepared that the site can be contaminated more than it is expected. This may lead to a significant increase in decontamination costs. The information about brownfields needs to be well structured. The knowledge base contains records that describe the individual sites and these records are precisely structured – this makes it possible to analyze, compare and find similarities between the investment alternatives. If the information is not well structured it is necessary to process this information before it is loaded into the knowledge base.

The information is collected usually from different sources. The data obtained from two different sources is different. It would be very complicated to write a software that would analyze and process the information automatically and such software would not always be reliable. Even if it is more time consuming - it is easier to analyze and process the data manually before the data is loaded into the knowledge base. The information about the brownfield sites should be publicly accessible. If the data is not accessible then it is necessary that the investor obtains and supplies the information so it can be loaded into the knowledge base. The information about the brownfield sites also has to be valid and up to date. There should also be enough time to collect and process all the information about the investment alternatives – if a set of for example two hundred brownfield sites should be analyzed it may take up to several weeks to collect and process the information so it can be used in the fuzzy model. Fuzzy modeling and testing of the model may also take a certain period of time. The process of redevelopment after the brownfield site is purchased may take from several months to several years so it should not be a problem if the decision making support process based on the fuzzy model takes several weeks. The time invested into the fuzzy model gives the investor a possibility to closely analyze and compare the individual investment alternatives and to see the similarities between different clusters of brownfields. These clusters emerge when the weights of the input variables are modified. After the fuzzy model is created it is possible to simulate different scenarios.

The objectives and needs can change to a certain degree in the simulation. Only requirement is that the input criteria of the model remain the same. Another requirement is that there are experts who provide qualified guess and estimation for unknown parameters which are required. Some criteria are too important so they have to be estimated if they are unknown. For example the true level of contamination is often not known yet this criterion is too important – it should be at least estimated by an expert opinion. Investor also has to have enough time for the redevelopment of the brownfield site – the process usually takes several months or in some cases may take even longer. If the investor does not have enough time then brownfield redevelopment is not the right investment decision. The investor also has to always supply all relevant information about the actual needs and objectives – if some important information or requirement is omitted in the process the method will not output correct recommendations. It is clear that the objectives of the investor may change but the changes should not affect the sets of criteria that are being collected about the brownfield sites. The process of data collection and processing requires significant amount of time. When all these prerequisites are met then this new research may be used.

3.2 Research time plan

This chapter contains a list of activities that were required in order to reach the set research goals. In a complex process working with large amount of information which may contain uncertain, unknown or incorrect information everything needs to be tested several times to make sure that the model and also the whole decision making support process is robust. If the proposed method of evaluation should be chosen by the real investors the method has to be reliable. It is therefore required to test different scenarios, various types of input variables and various amounts of input information. The research was conducted in three phases. First phase includes analysis of the research problem, sources of information, previous research conducted in this field etc. The second phase includes the activities related to the creation of the fuzzy model, testing and optimization of the process. Here is a detailed list of activities and milestones that had to be reached in order to reach the set research objectives.

First phase

- Analysis of the research problem.
- Analysis of the relevant literature.
- Analysis of the previous research conducted in this field.
- Analysis of the usual methods used by the decision makers.
- Analysis and evaluation of available existing fuzzy models.
- Definition of research objectives.

Second phase

- Evaluation of the criteria that will be frequently used by the decision makers.
- Generation of the test data.
- Creation of the initial fuzzy model for testing.
- Processing of the test data with the model and the evaluation of results.
- Adjustment and optimization of the fuzzy model.
- Thorough testing of the fuzzy model.
- Development of the supporting applications for the data collection and processing.
- Development of the supporting software applications for the evaluation of results.

Third phase

- Evaluation of the results.
- Thorough testing of the software.
- Thorough testing of the fuzzy model in different scenarios.
- Presentation of the new method to investors.

3.3 Relevant criteria for the decision making process

The investment appraisal process requires thorough analysis of various criteria. These criteria can be divided into several groups. In this research focused on brownfield redevelopment these criteria are specific. Certain criteria are the same for a brownfield site and for any other real estate. But certain criteria are special – for example the contamination of the brownfield site plays a very important role. In this research the criteria are divided into several groups. These groups are: general information about the brownfield site, geographic criteria, economic criteria, financial criteria and criteria related to ecology. A number of criteria in each group is listed in the following table. Each criterion is discussed in detail in this chapter because it is important for the implementation of the fuzzy model. The individual groups of criteria were also discussed in several research papers presented at international conferences.

Group name	Number of criteria
General information	5
Geographic criteria	6
Economic criteria	6
Financial criteria	4
Ecology	4

Table 1: Individual groups and a number of criteria in each group (Source: Own work)

3.3.1 General information about the brownfield site

First variable that is used in the fuzzy model is the identification number. Each investment alternative has a unique identification number which helps to identify the real estate. The set is usually very large and contains several hundred real estates – this is why it is important to be able to easily identify the individual real estates. Each online database assigns identification numbers and codes to the records contained in the database. Because the information about brownfields in this research comes from different databases it is not possible to use the foreign identification numbers but it is necessary to create a new database of brownfield sites with new identification numbers. However it is possible to access the original database later because the URL address of the real estate is stored.

Description	Variable name in the fuzzy model	Unit or variable type
ID	-	integer
Address	-	text
City	-	text
URL	-	text
Description	-	text

Table 2: List of variables in this group (Source: Own work)

Another unit of information which is very important for any real estate is its address. When address of the real estate is known the distance from the company purchasing the real estate can be easily calculated. In a time where all companies fight strong competition on the market it is very important to reduce costs. Some costs may be decreased more easily than others. After several interviews with managers of international companies it became clear that even big commercial enterprises with large profits try very hard to optimize the costs of logistics. It is apparent that the closer the new facility is to the firm's headquarters the lower the costs of logistics should be. Especially when the new facility assembles parts manufactures in other facilities. It is also strategically important to place the new facility close to the suppliers and customers. Investor has to have long-term plans which include possible changes on the market, new competitors, increasing prices of fuel and energy etc.

Redevelopment of a brownfield is a long-term process so it is not possible to decide about the purchase without long-term strategic plans which consider different scenarios that may occur in the future. Another key information about the brownfield site is the nearest city. Nearest city can be easily determined from the address of the real estate if the address is known. Region where the real estate is located is important because different regions can have different legislation – if the real estate is located far away from the company central the investor usually has less information about the region and fewer business contacts. The information about the nearest city also helps to group the brownfield sites into clusters which make it easier to work with the list. Usual advantage is that the further the brownfield site is located from other big cities the lower is usually the purchasing price. But it is clear that the costs related to logistics increase with distance. In some cases brownfields are coveted investment opportunities for large international companies who plan to build large plants in areas where there is high unemployment.

For the state such investment plans are very positive because several problems are solved at once. Old contaminated brownfield site is cleaned. New investment brings work for local construction companies and after opening of the new plant unemployment in the area decreases because hundreds of locals find jobs in the newly created facility. Brownfield sites are usually located strategically and their infrastructure is good.

URL address where additional information about the real estate can be found is important and has to be stored for future use. Although this information is not directly used in the fuzzy model this information is very important and has to be stored in the database as the investor will closely analyze and evaluate the investment alternatives selected by the fuzzy model as being optimal according to the requirements set by the investor in the initial step. After the reduction of the large set of possible investment alternatives detailed information can be easily accessed for the selected brownfield sites. Majority of information about the investment alternatives is collected from the Internet, therefore in most cases the URL address is available. Another advantage is that when the information about the brownfield site gets updated in the source database on the Internet. This updated information can be accessed thanks to the URL address. In order to keep the designed fuzzy model as simple as possible the knowledge base is not updated during the process of testing and simulations of different scenarios. Any change in the input data would negatively influence the accuracy of the model output.

General description of the real estate is also very useful. Not all information can be included in the designed fuzzy model. The set of parameters is reduced to a set of several simple parameters yet after the set of alternative investment decisions is reduced the investor starts to analyze the smaller set in greater detail – for example the reduced set can include about one dozen brownfield sites which fit the investor requirements better than the remaining sites. The investor then starts to collect additional information about the selected brownfield sites from the general description and from the Internet with the help of the stored URL address which points to the source where the information about the brownfield site was obtained.

3.3.2 Geographical and engineering criteria

This group of criteria includes several important criteria related to geography and engineering namely these criteria: distance from firm's headquarters, the quality and availability of required infrastructure, the availability of specialized equipment and the possibility of future extensibility.

Description	Variable name in the fuzzy model	Unit or variable type
Distance from the investor	Di	km
Infrastructure	In	%
Specialized equipment	Se	%
Future extensibility	Ex	%
Availability of qualified workforce	Ps	%
Positive attitude of local community	Pa	%

Table 3: List of variables in this group (Source: Own work)

Distance from firm's headquarters is an important criterion because it has a significant impact on the purchasing price and on the costs of logistics. The further the real estate is from the nearest big city the lower the purchasing price usually is when compared with the real estates located near the big city. Real estates located in the vicinity of other industrial areas provide many advantages. Most facilities require regular shipments of components and materials. Lower purchasing price may seem like a great advantage at first but it is necessary to calculate or at least make a good estimation of the costs of transport.

It is usually more strategic to pay higher purchasing price and save on the costs of logistics than save on the purchasing price and then pay more for every shipment of components or materials. The prices of fuel increase steadily so even though the costs of transport seem high right now these costs may become much higher in the near future. Therefore a good strategy for any investor would be to try to find a brownfield site that is located close to the suppliers and customers.

Quality and availability of required infrastructure is also very important. Each investor has different needs and requirements. If a company manufactures heavy machinery it would be a great advantage if the brownfield site has a connection to the railway. Some components may be so heavy that they might not be transported by trucks. Such requirement of course significantly reduces the set of possible investment alternatives. Another company may require a large parking lot or a good access to highway.

Quality of infrastructure is very important for most commercial enterprises. Another investor may require a large warehouse where the products can be loaded directly into trucks. If a brownfield site was used for a similar type of business in the past it is an advantage – infrastructure is probably already there but the investor will only need to invest into its modernization. If a company uses energy intensive machinery or processes there has to be a sufficient connection to the power grid. Making changes or improving the infrastructure is usually very expensive. For example to build a new road to connect the new facility with the highway may cost more than is the purchasing price of the brownfield site. Another large investment is the redevelopment. The investor has to therefore make precise cost estimates and calculations even before the brownfield site is purchased.

Investor can also require the availability of specialized equipment. This may include for example a crane, silo, large warehouse, loading docks, cooling tower, chimney etc. Here is another great example how can a similarity in a type of business the old and new owner of the brownfield positively influence the costs. The specialized equipment usually needs to be examined and tested but after investing into its modernization the new owner saves a lot of expenses that can be invested elsewhere. It is usually less expensive to repair than to purchase brand new equipment of this type. For example even if there is an old crane that has to be replaced the area around the crane is adapted and the place is easily accessible by trucks. If there is no crane everything has to be adapted even before the crane is installed. These adaptation costs can be very high and the process of adaptation may take several months before the new facility can start to operate.

Possibility of future extensibility is also a very important criterion. Investor makes a large investment project in order to reach the long-term strategic goals. The purchased site should provide the possibility to grow. It is therefore wise to purchase larger brownfield site even if it may be more expensive. Brownfield sites available for purchase are usually very large. Small brownfield sites were already purchased and redeveloped. States and governments wish that even the large brownfield sites are redeveloped so there are even incentives for private investors which aim to make the large brownfield sites more attractive. The costs related to logistics also play a role here. It is less expensive to have one large facility than to have three small facilities and move the components and materials between these three facilities.

Building a modern manufacturing facility on a redeveloped brownfield site is not enough. Without the qualified workforce the facility will not be profitable. The availability of qualified workforce is another very important criterion which has a significant influence on the decision the investor will make. Therefore it is important to include this information in the fuzzy model. When thinking about a long-term investment decision of this type the investors have to consider also if there are enough people who are willing to work in the new facility and if they are qualified enough. Another criterion related to the previous one is the positive attitude of local community. If the investor is widely known and there is a certain opposition it is necessary to include this criterion into the fuzzy model. If the investor builds a new facility and the attitude of the local community is negative it may be very difficult to get qualified workers. The company would probably need to offer higher wages to the workers and use other incentives to win the local community on its side again.

3.3.3 Economic criteria

Information in this chapter was presented at an international scientific conference (Brož, 2011). First and key economic criterion is the purchasing price or monthly rent of the real estate. The investor has to think economically and make plans of future profits and costs. Buying new brownfield requires long-term strategic planning. The investor has to decide whether it is better to purchase the real estate or to rent it. Purchasing price is usually very high and requires a significant amount of financial resources. Renting such property may be cheaper in the short-term.

Description	Variable name in the fuzzy model	Unit or variable type
Price	Ce	Kč
Area	Ro	m2
Estimated costs of logistics	Do	Kč
Estimated fixed costs	Fc	Kč
Basic requirements	Zp	%
Special requirements	Sp	%

Table 4: List of variables in this group (Source: Own work)

The investor has to go through both alternatives and decide to either purchase or rent the new real estate. Brownfields are specific in that they can have a very low purchasing price because the owner – in some cases a municipality or the state – aim to provide advantages for investors who are willing to redevelop large unused brownfields they own. This lower purchasing price may subsequently lead to much higher overall costs as it takes additional resources to remove the contamination from the brownfield to meet the new stricter ecological regulations. When renting a new real estate the investor does not have to solve these problems as the real estate is not his property. In the long-term renting some large real estate can become even more expensive than buying it. Even if the investor has long-term strategic plans about the development of the business some unexpected changes may occur on the market that could force changes in these long-term plans. When such change occurs it is much easier to stop renting real estate and shift focus of the company to some other activity. When the company loses interest in a newly acquired brownfield it is usually not easy to find a buyer or to get a good price for the property that is being sold.

Another basic criterion of a real estate is the area in square meters. The designed decision support model uses this criterion to evaluate the different investment alternatives – different real estates have different prices and their area can vary. Brownfields close to city centers can have smaller area and very high selling price. And real estates further from big cities can have large area and very low price. Because of this it is not easy for the investor to make the optimal decision because the alternatives differ and there are many criteria. Large real estate has several advantages. For example the part of the newly purchased property can be used for different purposes. If the investor has enough resources it is advisable to purchase larger real estate even if it has higher purchasing price. Additional space can be used for warehouses, parking lots and even for example as a space for solar panels. The objective of the investor is to use the new real estate as efficiently as possible. When purchasing brownfields the state usually provides help or advice. Brownfields are usually located near big cities and have good infrastructure. Instead of using greenfields for new factories it is logical that the state would like investors to reuse existing brownfields and provides help to remove the contamination left there by previous owners.

If some brownfield is far away from the other operations of the investor it is clear that the investor will have to spend more on logistics because materials or wares will have to be transported further. Different companies can therefore value same real estate differently because they are located in different parts of the state. Criterion closely related to the distance from other operations of the investor company is estimated monthly costs of transport or logistics. Important trend in business right now is to reduce costs. Even large companies face strong competition on the global market. Several managers from large companies claimed that only space for reducing costs is with improvements and savings in logistics. These costs are closely correlated with the distance of the newly purchased real estate from other operations of the investor. The investor would therefore prefer to buy the real estate that is the closest to suppliers and customers. Because there are many different business companies on the market there is a high probability that the demand for these real estates is much higher than the supply – therefore these real estates will have much higher price than others.

If there is a large industrial cluster with many businesses cooperating with each other trying to find a real estate available for purchase for a low price can prove to be very difficult. The investor has to often search elsewhere. With good strategic planning the investor often manages to find competitive advantages and discovers new possibilities for growth.

Another criterion important for the selection of optimal real estate is the calculation of monthly fixed costs. Some real estates can have high fixed costs. Obviously the lower costs the business has the lower it can set the price of its products and services. The objective is to find a real estate that has lowest possible fixed costs. When comparing real estates that can be bought and rented. Those that can be bought require much higher initial spending for the purchase and then require additional resources for adaptation of the real estate for the needs of the investor. Before the property can be used it usually requires this adaptation. After the real estate is purchased the investor does not pay rent and the fixed costs are very low.

If the investor chooses to rent the property instead of purchasing it investor does not have to pay the purchasing price but pays rent for using the property to the owner. Rent causes the fixed costs to be much higher. But renting the property also has its advantages. The business company can stop renting the real estate and move elsewhere with very low costs. Renting a property allows business to be more flexible as it does not require large amount of resources frozen in the real estate after its purchase. SMEs often choose to rent the property because they do not have enough resources to redevelop whole brownfields. Large companies that have much more available resources can sometimes prefer to buy large brownfields because they see their future potential and consider them to be great opportunities for making profit.

Another criterion in the designed fuzzy model is the fulfillment of basic and special requirements. The model is designed to be versatile so it can help investors that have very different requirements. Therefore the requirements the investors have were split into two categories. Basic requirements that can include for example the need for warehouse, access by railroad, energy availability for large industrial installations and devices. Experts from the company have to determine how well the investment alternative fits these basic requirements. In order to keep the model simple the individual requirements are not listed but they are grouped into these two groups.

Basic requirements include those that are common and most investors would list them as important for their needs. It is clear that some investors will have special needs and their manufacturing processes or technology differs from other producers. For these special needs a criterion was added into the model called fulfillment of special requirements. These special requirements can include for example availability of large amounts of fresh water for chemical processing of materials and similar requirements that can the investor have. If the investor would have to transport large amounts of water it could significantly increase the costs of logistics and in end result could have a negative impact on the whole business. Having such special requirements often limits the set of alternative investments.

3.3.4 Financial criteria

This group of criteria includes several important criteria related to finance namely these criteria: necessary investments for adaptation, expected short-term investments, expected long-term investments, expected future investments related to ecology (due to change in legislation etc.), availability of EU or state funding for redevelopment.

Description	Variable name in the fuzzy model	Unit or variable type
Costs of adaptation	Ad	Kč
Required short term investments	I1	Kč
Required long term investments	I2	Kč
Availability of EU and state funding	Fu	%

Table 5: List of variables in this group (Source: Own work)

The investment appraisal process requires thorough analysis of various criteria. These criteria can be divided into several groups. In this research focused on brownfield redevelopment these criteria are specific. Some criteria are same like when an investor decides about any other real estate. But certain criteria are very special – for example the brownfield pollution plays a very important role. In this research the criteria are divided into four groups. These four groups are: geographic criteria, economic criteria, financial criteria and criteria related to ecology. This chapter discusses in detail the evaluation criteria related to financing. First evaluation criterion is the necessary investment for adaptation. If a business company decides to purchase a new real estate it is clear that the new real estate will not suit the needs of the investor without any adaptation.

Therefore it is wise to consider this adaptation. Of course this adaptation takes time and costs certain amount of resources. When purchasing a building or a warehouse the real estate is usually equipped with the required infrastructure and adaptation costs are not high. When purchasing a brownfield site these costs for adaptation can be very high. Brownfields are usually left unused for long periods of time and they deteriorate. Many repairs and changes are required in order to start using the brownfield. It is usual that some important equipment or infrastructure is missing and it is necessary to build it.

It would be a mistake to omit these costs that may be high for some investment alternatives. Investor has to calculate the estimated time and amount of resources it will take before the new real estate can be used for intended purpose. To make a good estimation the brownfield has to be closely inspected by experts. Especially for the long-term investments on this level the resources spent on close analysis or the real estate is a good investment. It can prove to be very expensive to purchase a real estate without thorough analysis preceding the purchase. The cost of adaptation can make the investment much more expensive.

After the purchased real estate was adapted to the needs of the investor and it has started to serve the intended purpose the investor has to make a plan for the use of the real estate in the future. Long-term investments require long-term planning. Initially the investor can make a plan for expected short-term investments for the time following the purchase. It is a good choice to buy a property that is bigger than the momentarily needs of the investor even if it requires more resources. Buying one large real estate that provides enough capacity even for the needs of the investor in for example five or ten years is a good choice because it would be much more expensive to buy two or three separate real estates as the business grows. Brownfields are usually much larger than other real estates that are available for purchase. Before the purchase the investor has to have a good plan how to use the property in the future efficiently. It would be unwise to left the free capacity of the purchased property unused. Even if it requires some resources to prepare the free capacity it is a good investment. Before the additional capacity can be used for manufacturing it can be utilized as warehouse or other storage capacity. Even as a place to park the fleet of trucks etc. Or the investor can rent the free capacity to other businesses when there is a demand for it. As the economy grows the prices of real estates increase. It is possible to expect that the investor would pay much higher price for the real estate in the future. Short-term investments may include for example improvements of infrastructure, repairs etc.

For example if there are large buildings that house manufacturing lines the investor can choose to invest into insulation of these buildings. This investment decreases the costs of heating. Just like the price of real estates the price of energy will increase significantly in the future. The short-term investments are separated from the adaptation investments after the purchase as these two items can be very different. Another criterion for the investment appraisal is the expected long-term investments. This criterion will include the investments that are required in the future – especially three and more years after the purchase. Some infrastructure may become insufficient or damaged in the future and may require relatively large investments. The future possible uses that require investments should not be put into this criterion directly. Only required investments should be included.

Certain brownfield sites provide a great possibility for future extensibility and that would of course require large investments so putting these investments into this criterion before the comparison with other investment alternatives would make the investment alternative less attractive. The designed model relies on the expert opinions and estimates of the investor. Certain criteria can be determined precisely from the available information but other criteria can be determined only the investor. The expected long-term investments is one criterion that cannot be determined easily without the investor. The investor can decide about the future use of the property before it is purchased. For example the investor can use the property for manufacturing for five years and then can decide to move manufacturing to another country if the price of work becomes too high. After that the property will be used for other purpose. It can be rented or it can be sold or redeveloped to serve another purpose. Purchasing a brownfield provides many possibilities yet it also brings risks. When thinking about the future the investor has to keep in mind that the company will evolve and its needs will change as well. The vision and long-term objectives may change. And also the focus of the company may shift. If the company itself will not change then the customer needs and the market itself may change. What was an excellent investment at some point in the past may become a burden for the investor in the future. The investor should have several different scenarios for the possible uses of the property.

Another financial criterion is the expected future investments related to ecology. Ecology is closely related to sustainable development. EU uses its power to influence businesses so their operations have to become more energy efficient and do less harm to the environment. In order to enforce these goals new legislation is issued which allows the government to punish those businesses that break the rules. It is wise to include this criterion into the investment appraisal process. Especially when dealing with brownfields that have the notorious reputation of being polluted by dangerous chemicals and heavy metals. It is in the common interest to redevelop brownfields. The business that previously owned a brownfield may not exist anymore or the business does not do well enough to be able to remove the contamination. In an economy where profit is the top priority it may be cheaper to leave contaminated brownfield behind and move elsewhere. Yet this approach is very irresponsible.

Businesses should avoid making decisions like this. Looking for profit at all costs hurts the environment and the community. Governments will look for ways to punish such businesses as what helps a single private company can hurt everyone else. If the investor purchases the brownfield with certain level of contamination it may be able to comply with the ecological standards now but not in the future as the legislation may become more strict. These changes in legislation will require significant investments in the future. Brownfields are the most risky investment the investor can make when considering this particular criterion. And the last criterion is the availability of EU/state funding for redevelopment. Government and people living around the brownfield site always wish that an investor redevelops the brownfield site. Some brownfields may be on the list of real estates that are eligible for receiving subsidies that help the investor to remove the ecological contamination. Such subsidies are available for certain brownfield sites this makes them clearly more attractive for the investor. But of course such advantage always comes with a price and that is the contamination of the site.

3.3.5 Ecology

Information in this chapter was presented at an international scientific conference (Brož, 2011). This group of criteria includes several important criteria related to ecology namely these criteria: fulfillment of basic requirements on ecology, level of pollution, uncertainties in liability for contamination and expenses related to the removal of pollution. Each of these criteria is discussed in greater detail here.

Description	Variable name in the fuzzy model	Unit or variable type
Estimated contamination	Po	%
Basic requirements on ecology	Be	%
Expenses related to removal contamination	Er	Kč
Future investments related to ecology	Fe	Kč

Table 6: List of variables in this group (Source: Own work)

Following text discusses several individual ecological evaluation criteria that are important for investors when they are planning to purchase a brownfield. Brownfields usually have a certain level of contamination by heavy metals, oil and various other chemicals. In the past the ecological legislation was not as strict as it is today. Also there were many large industrial facilities operating in the Czech Republic in the past that were utilizing technological processes that used various dangerous chemicals. As time passes these dangerous chemical compounds get absorbed by the soil and the building materials in the brownfield. Before investor purchases the brownfield it is very important to assess the level of contamination. European Union and local government implemented strict standards that forbid businesses to pollute the environment and forbid workers to work in unhealthy conditions.

Determining the true level of contamination may be very difficult as previous owners sometimes tried to conceal the problems to avoid being punished. Experts have to visit the site and take samples so the soil from the brownfield can be analyzed in the laboratory. During past decades researchers devised new methods that allow safe decontamination of soil. Yet using these methods to clean the contamination of course takes time and costs the investor certain amount of resources.

Also the determination of the true level of contamination takes a certain amount of time. If the investor chooses between many alternatives there is usually not enough time to perform a thorough analysis of the ecological contamination of each brownfield. In this case the level of contamination has to be estimated by experts based on the technological processes the previous owner was using during manufacturing. The government is interested in redevelopment of brownfields so it can provide a valuable help in assessing the level of contamination and can even provide subsidies that make it easier for the investor to remove the contamination from the site and starting to use the brownfield for new purposes.

Closely related with the level of contamination are the expected expenses related to the removal of the contamination. Some brownfields may be polluted by chemicals that are easy to remove and some can be polluted by compounds that are dangerous and cannot be easily removed from the site. Investor has to ask experts in this field to make an estimation of the costs of complete decontamination of the site before it can be used by the investor. Brownfields are often sold at very low prices but this price is then significantly increased by the costs of decontamination. This evaluation criterion is therefore very important especially when dealing with brownfields. Next criterion is the fulfillment of basic requirements on ecology.

The designed decision making support method is intended for broad spectrum of investors that can have very different requirements including ecological requirements. For example the investor may manufacture food or beverages and may require steady supply of clean water. Of course having these special requirements may severely limit the number of investment alternatives that suit the needs of the investor. Final evaluation criterion is the uncertainty in liability for contamination. There may be legislative issues related to the contamination of the brownfield. This criterion records the measure of uncertainty related to the liability.

This is the set of general criteria that are used during the development of the test models as well as for testing with information about real estates that are available for purchase on the market. This set was carefully selected and should cover most criteria that will be required by managers who are making decisions about the purchase of new realty. However the method is designed so that it can use any new criteria that fulfill certain rules. These rules have to be followed due to the nature of fuzzy logic. The proposed method has to be very flexible and the objective is also to use this method as a support of the decision making process in different fields that also have a large number of possible decisions and also have a similar set of relevant criteria. In this case the method is optimized for the use in real estate investment.

3.3.6 Additional criteria

Each investor has different needs so a set of criteria will be different for each investor. In this work a set of general criteria is defined. This set of general criteria should be useful for most investors. The fuzzy model is designed to be universal so it is easy to use different criteria. The set of criteria is defined in the initial phase of the process. In next step the information is collected and the required set of criteria is then loaded into the knowledge base. Some of the criteria will be used by most investors – for example purchasing price, area, address, adaptation costs etc. But some criteria from the defined set of general criteria will not be useful for the investor instead the investor will need to add different criteria based on the objectives and needs of the company. This chapter discusses the possible additional criteria. The fuzzy model is prepared to work with different criteria. Here are some examples of criteria investor may require. For example the brownfield site configuration may be very important if the investor has special requirements on the layout and accessibility of the site. Other criteria may be related to the level of contamination. For example the investor may require the detailed contamination characteristics. The true quantity of the contamination, toxicity of the contamination, solubility of contaminants in acid rain etc.

3.4 Sources of information

One of the advantages this new research offers to the investors is that the system is designed to analyze a very large set of investment opportunities. In order to work with a large number of possible investments the system requires to have a large amount of information available. This information describes the alternative investments in detail. Each brownfield site can be described by a set of criteria. Investor chooses which criteria are relevant for the decision making process. Some information about the brownfield site may not be relevant so it is of no use to collect and store this information – redundant information would slow down the processing speed. It is possible to collect the information about all investment alternatives manually from printed materials or contact the sellers via telephone but this process is not efficient enough and very slow.

The amount of information included in the printed materials is limited and the information is not up to date. This problem can be solved by using online databases of real estates. Current online databases contain detailed information about thousands of real estates available for purchase. Especially now after the mortgage crisis the prices of real estates decreased and there are many interesting opportunities waiting on the market. The amount of information available online is so large that it was necessary to develop and implement an efficient system for data collection and processing. This system will be discussed in detail in the next chapter.

There are three ways to obtain the required information for the fuzzy model. The investor can supply the information about the investment opportunities. In this case the investor did prior research and collected information. In this case it would not be necessary to download and process information from online databases. But most investors do not have enough time to research all investment opportunities. Therefore a system for information collection and processing was created. Investor then only specifies his investment objectives and roughly specifies which brownfield sites fit the requirements. This phase is very important as the formulation of key requirements and objectives is used in all steps of the process. Investor must not omit any important detail that may influence the final decision. The fuzzy model would then provide incorrect recommendations.

After the formulation of requirements and desired specifications the process of data collection can begin. There are several large databases of real estates on the Internet. For example www.sreality.cz, www.reality.cz, www.nemovitosti.cz, www.digireality.cz and others. One database is particularly useful for this research because it contains only brownfield sites. This database can be found at: www.brownfieldy.cz/seznam-brownfieldu. These public databases contain all real estates both for private investors and for commercial enterprises. Some brownfield sites are not listed in these online databases. Information about these brownfield sites can be obtained from the state or from government officials. There are also databases which contain only the brownfield sites. These databases make it easier to get the required information. In order to find as many investment opportunities as possible information from all these sources can be downloaded and processed. The data collection process in this research is designed so that it can collect as much information as possible. When the information is collected and processed it can then be filtered easily. Therefore the fuzzy model works with a large set of investment opportunities – not only with several brownfield sites. This is one of the advantages of this new research.

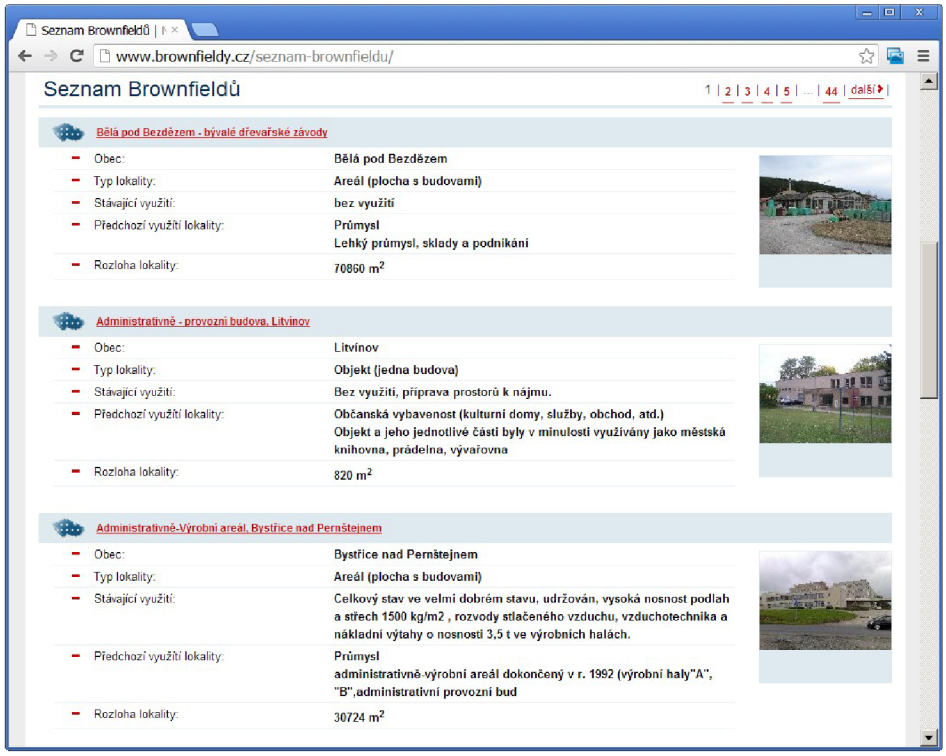

Figure 5: Online database of brownfield sites (Source: www.brownfieldy.cz)

The investor can specify which online database should be chosen and how many investment opportunities should be included in the process. The ideal number of real estates in the fuzzy model should be between fifty and four hundred. Most online databases offer a search of filtering option which can be adjusted to display only real estates that fit the rough requirements set by the investor. This filtering removes the majority of the real estates that do not fit the specified requirements. For example if there are more than twenty thousand real estates available in the online database after filtering this number can be reduced to for example sixty real estates. The detailed information about these real estates is then downloaded from the Internet. The downloaded files cannot be directly used in the fuzzy model because the fuzzy software requires a special format of the knowledge base. It takes several steps to convert the downloaded files into the knowledge base. This process will be described in the next chapter.

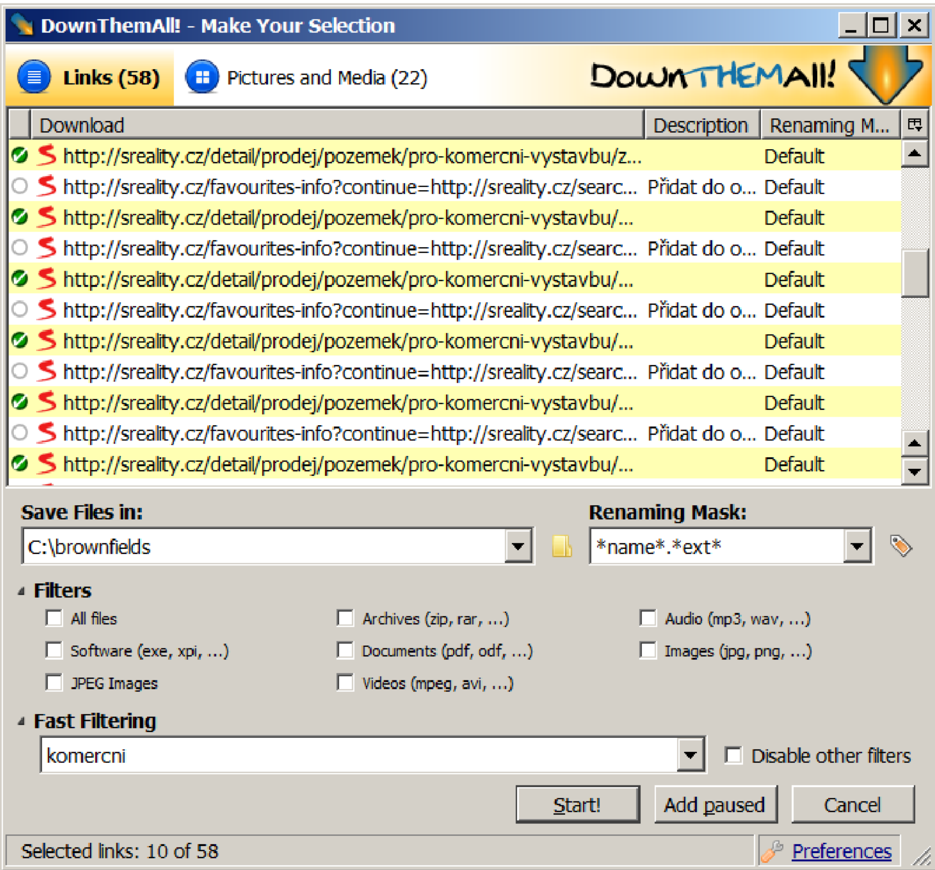

Figure 6: Automated download from an online database (Source: Own work)

3.5 Data processing

The downloaded files containing the information about the selected real estates have to be processed in order to use this information in the knowledge base. A set of applications was developed in the Java programming language. These applications allow to efficiently process thousands of downloaded web pages and to extract the relevant information about the real estates in the required format. Data analysis and processing is necessary because the information data does not come from a single database containing information about real estates available for sale. It would be much easier if all the information would be available in one database – but this is not the case.

Each real estate database can contain good investment opportunities and there is no single online database containing all the real estates which are listed in other databases. Because of this the system has to be able to collect as much information as possible from different sources and databases. Data processing is not an easy task because different databases always use different format in which they store information. The information does not have to be extracted manually – to edit hundreds of files manually would take a very long time.

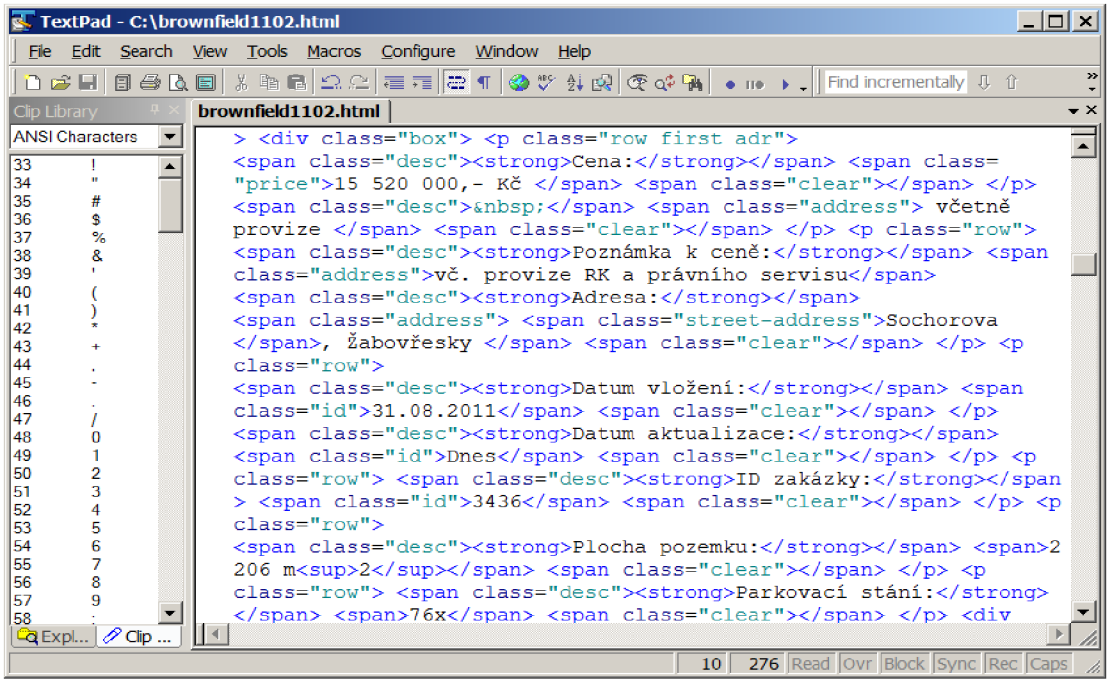

Figure 7: Information about real estate stored in the HTML language (Source: Own work)

Because the information about the real estates available for purchase becomes outdated very quickly it is necessary to collect and process this information efficiently. Most records from a single database can be processed with a single set of defined rules – this is possible thanks to the hypertext markup language (HTML). This is the universal languages for creating online content on the Internet. If the information is collected from six different online databases then six sets of data processing rules have to be created. These data processing rules allow the special data processing software which was created for this research to quickly process hundreds of downloaded files in several seconds. The creation of these data extraction rules requires a certain amount of time and careful analysis of the downloaded files. This step is complicated and cannot be done automatically. After initial analysis of the research problem it became clear that the whole process from the data collection to the final reduced set of investment opportunities recommended by the fuzzy model is too complex and cannot be done by a single software application. Many complex operations are required in the process.

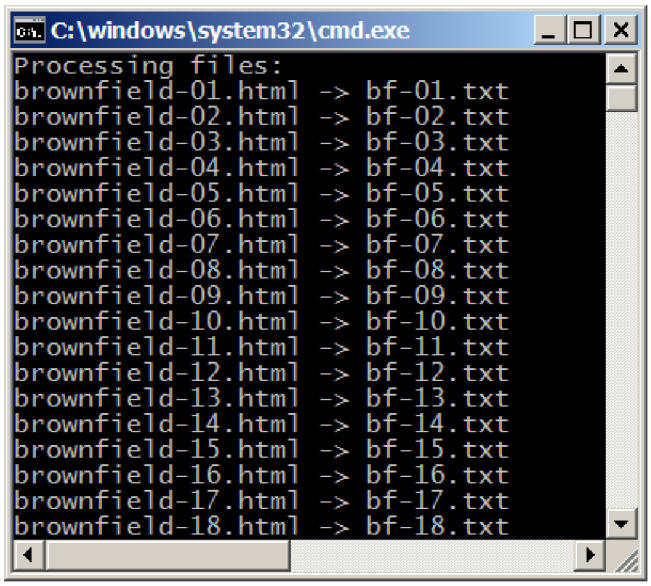

Figure 8: Software for automated data extraction and processing (Source: Own work)

Therefore instead of implementing the new decision support method as a single computer application it is better and easier for the investors if the whole process is offered as a service. This way the investor has more control over the process and can influence the process in different stages. If a single software should perform all the required tasks it would not be reliable or the software would be very complex and would require a very complicated configuration. For example even the initial step of data extraction from the downloaded files is very complicated and very difficult to program. Also the information acquired from the online database is not complete. Some of the basic criteria are contained in the online database. But many other important criteria are not. This information has to be added manually before the knowledge base is created. Once the application processes the downloaded files a simple table is created. This table is can then be checked and corrected manually. New information can be added into the table. For example none of the online databases contained information about the true level of contamination of the brownfield sites. This information has to be added manually – it can be either found in other materials or it can be estimated.

It is a great advantage for the investor if there is a possibility to consult these matters with environmental experts and chemists. The researched decision support method is optimized for brownfield sites but with slight modification of the criteria the fuzzy model uses it can be used for other real estates as well. Both for private investors and for firms. The data collection and processing software is universal and with slight modification it can be used for similar operations – for example other information can be extracted from the files. The applications can also process files from other online databases. With different rules other information can be extracted. This makes the developed applications very useful. The applications created for this research have already helped to collect and process information for other scientific projects conducted by my colleagues.

Id	Id	1
Address	Ar	Rojetín
City	Ci	Rojetín
URL	Ur	http://sreality.cz/detail/prodej/komercni/vyroba/rojetin--/827106140
Description	Ds	Prodej objektu bývalého lihovaru v obci Rojetín. V objektu se nachází funkční – zakonzervovaná technologie na výrobu surového lihu, případně je možné využít technologii na výrobu biopaliv. Objekt se nachází na okraji obce a stojí na vlastním pozemku. V případě zájmu, lze dokoupit i pozemky ostatní, které jsou prozatím majetkem pozemkového fondu. Na
Distance (km)	Di	38
Price (Czk)	Ce	3300000
Area (m2)	Ro	4191

Table 7: Sample information collected about a brownfield site (Source: Own work)

3.6 Statistical approach

In order to check the results of the fuzzy model a statistical approach is used to calculate a set of numerical values. These calculations are performed independently on the fuzzy calculations and output different results. Classical statistical approaches do not allow the work with fuzzy input information. The fact that fuzzy information is present in the input data meant that a new method of calculation had to be used in order to obtain results which can be compared. Statistics can easily compare individual numbers or vectors of numerical values. However in this case the information about some brownfield site may not be known or may be known to be imprecise or wrong. Therefore the fuzzy model contains the option to set the value of the input variable to unknown. The individual statements of the knowledge base can be seen as four groups of variables. Each group includes different variables – for example economic, financial etc. Each group consists of several variables. This group of variables can be seen as a vector of numerical values. It has to be noted that this vector may include a variable that does not have a number assigned in the case that the information is not available. In order to compare the numerical values and simplify the fuzzy calculation a system of fuzzy sets is used. These fuzzy sets are ordered from the least suitable value for the investor to the most suitable. Thanks to this all variables are converted from absolute values to a scale from zero to one hundred. With this simplification the individual variables and even the groups of variables can be compared with the help of a simple arithmetic average. The higher value is calculated the more suitable is the analyzed brownfield site for the investor.

The problem is that the input data includes unknown variables. The unknown variables cannot be set to zero because the numerical value zero signifies the least suitable possible value. Instead the variable is left empty. When a simple arithmetic average would be calculated from such vector it would include only those variables which have a set value and so the calculated average would not be correct. For example if only one variable is known and its numerical value is ninety then the calculated average from this group of variables would also be ninety – which would mean that the investor would get incorrect information about the brownfield site. The site would look like it suits the requirements very well but instead very little true information would be available and the brownfield.

In order to solve this problem additional numerical value is calculated. This value records the ratio of known to unknown information. With this calculation the information about unknown variables is precisely recorded. The simplest statistical method to analyze the input information is therefore to calculate two numerical values for each group of variables for each brownfield site. For four groups of variables eight numerical results are calculated. With these eight values which include four arithmetic averages and four ratios of known to unknown information the brownfield sites can be relatively easily compared.

Calculation of the arithmetic mean:

$$A = \frac{1}{n} * \sum_{i=1}^{n} x_i$$

Calculation of the known information ratio:

$$KI = \frac{Number\ of\ known\ parameters}{Number\ of\ total\ parameters}$$

The calculated results of this statistical method should of course output the same recommendations based on the requirements of the investor. However it is clear that this statistical calculation does not provide the large amount of information about the knowledge base compared to the approach which uses the special fuzzy software. The special software allows to easily find existing similarities between statements in the knowledge base. Also the results of the fuzzy model can be visualized, analyzed and interpreted graphically. It would be possible to calculate the overall average and ratio of known to unknown information for each individual brownfield site but such values would be very inaccurate and it would not be possible to perform a direct comparison. This limitation is caused by the complexity of the input information describing the investment alternatives. Therefore it would not be possible to use only the statistical approach for this research problem. Several different approaches are required in order to confirm the results calculated by one method or approach.

	Arithmetic average				Known information			
Statement	Geographic	Economic	Financial	Ecology	Geographic	Economic	Financial	Ecology
1	66,67	58,33	72,5	70	1	1	1	1
4	60	66,67	87,5	60	1	1	1	1
12	51,8	54,25	26	72	0,83	0,67	0,4	0,5
16	55,2	44,67	44	70,75	0,83	0,5	0,8	1
20	69,5	32,33	38	54	1	1	0,4	0,75

Table 8: Sample results obtained with the statistical approach for several statements (Source: Own work)

3.7 Fuzzy model

The fuzzy model is the key component in this research. Fuzzy models were successfully used to solve other economic problems including (Brož & Dostál, 2012) and (Bočková et al., 2012). The model allows sophisticated analysis and evaluation of the input data. The data and the evaluation criteria have to be preprocessed and converted to a special format that is used by the proprietary fuzzy logic software used in this research. The collected information has to be first assigned to fuzzy sets. These sets can have a different resolution as can be seen in the following two figures.

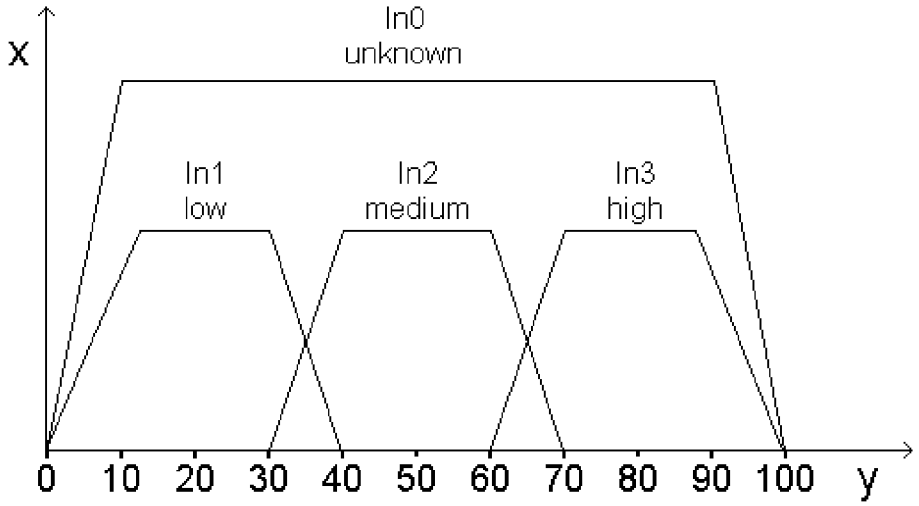

Figure 9: Grades of membership in four fuzzy sets (Source: Own work)

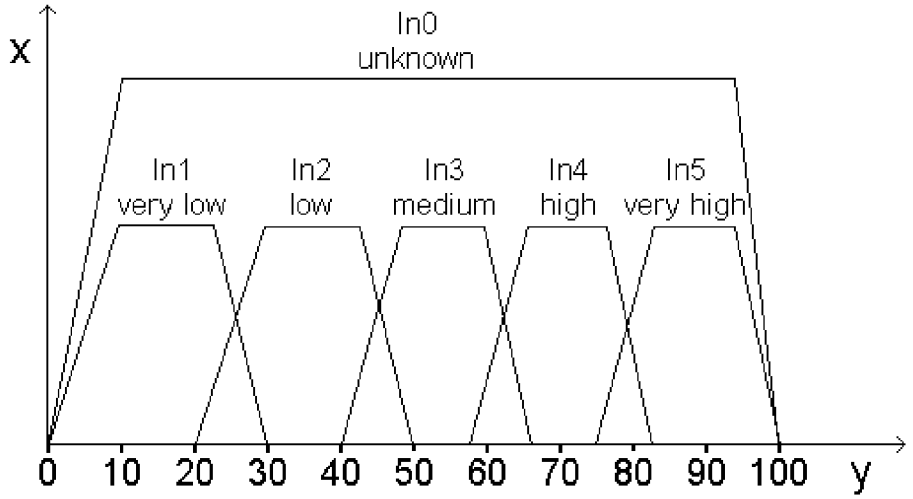

Figure 10: Grades of membership in six fuzzy sets (Source: Own work)

Following table records the individual fuzzy sets and intervals used for the area of the real estate – measured in square meters. Instead of listing all twenty tables just one was selected for this chapter. In order to simplify the fuzzy model a different order of fuzzy sets has to be used for criteria where higher value is worse for the investor. For example prices and costs have this reversed order. This measure allows to work with the values of the fuzzy model with common statistical methods. Without this measure the statistical calculations would output incorrect results. This reverse order also makes it easier for the fuzzy software to work with the fuzzy knowledge base. Inverse proportion in the input data and fuzzy sets would make the processing even more complex as it would be required to record this information for each variable.

Fuzzy set	Area in square meters	
	Lower limit	Upper limit
Ro0	unknown	
Ro1	0	199
Ro2	200	399
Ro3	400	599
Ro4	600	999
Ro5	1000	1999
Ro6	2000	4999
Ro7	5000	19999
Ro8	20000	49999
Ro9	50000	unlimited

Table 9: Fuzzy sets and assigned intervals (Source: Own work)

When the fuzzy logic software is launched a set of parameters is inputted. These influence how the application processes the fuzzy knowledge base. These parameters for example influence the number of real estates that will be included in the result. It is also possible to influence the threshold for finding similarities in the input data. Same model with different settings can result in very different results – it depends on the parameters that are entered into the software before the calculation begins. The fuzzy model has certain limitations. The most significant limitation is the amount of the input data and criteria that can be entered into the model. The limitations will be discussed in greater detail in a special chapter. It is also possible to interact with the fuzzy model. The processing of the input data is not only a single operation performed by the computer but it can also be a fuzzy dialogue between the user and the fuzzy model.

The model is processed several times based on the reactions of the user who analyzes the intermediate results. The fuzzy dialogue will be discussed in a special chapter. A set of brownfields specifications represents a complex and very vaguely defined system. Once the information about the investment alternatives is collected and processed a single table is created. This table contains details describing the individual brownfields. Each brownfield site is described using the same variables - this allows to perform the initial analysis of the input data before the information is converted for the fuzzy model. The fuzzy model does not directly work with absolute values contained in the input data. The information has to be converted into statements. The set of fuzzy statements describing the individual brownfields is studied. These statements consist of a combinations of variables describing the intervals containing the absolute value describing a single variable of a single brownfield. Names of these intervals consist of codes combined with numeric values and are ordered from least suitable for the investor to the most suitable. This order simplifies significantly the fuzzy model as indirect proportion of some input variables would make it much more complicated for the fuzzy model to compare the individual statements.

If a certain variable is unknown a special interval is used. The name of this interval contains a zero. This special interval plays a very important role in the fuzzy model. Thanks to this interval the model can work with brownfields which are vaguely described because there is not enough information available. An example of several statements from the knowledge base can be seen in the following table. There are 101 statements representing 101 investment alternatives. Because the knowledge is so large only statements 8 to 17 were selected for this chapter. The whole brownfield fuzzy knowledge base can be found at the attached CD. Di3, see upper left corner of the following table, is a fuzzy set. Once the knowledge base is created it is processed by special fuzzy logic software. This software reads the knowledge base and performs calculations which analyze and compare the individual statements. The software outputs a file containing the numerical representations of similarities between individual statements – sample output file can be found in Appendix 2.

8	Di3	In5	Se9	Ex9	Ps5	Pa8	Ce9	Ro9	Do4	Fc5	Zp5	Sp8	Ad9	I14	I27	Fu3	Po9	Be6	Er9	Fe9	1
9	Di5	In9	Se8	Ex2	Ps6	Pa8	Ce9	Ro9	Do6	Fc6	Zp9	Sp7	Ad4	I17	I24	Fu7	Po9	Be9	Er6	Fe9	1
10	Di6	In9	Se6	Ex6	Ps9	Pa9	Ce5	Ro9	Do5	Fc8	Zp5	Sp6	Ad9	I18	I29	Fu9	Po8	Be9	Er9	Fe9	1
11	Di0	In7	Se0	Ex0	Ps9	Pa0	Ce3	Ro6	Do4	Fc7	Zp0	Sp8	Ad1	I19	I20	Fu0	Po9	Be0	Er6	Fe0	0,8
12	Di4	In7	Se8	Ex6	Ps0	Pa4	Ce4	Ro7	Do0	Fc0	Zp3	Sp9	Ad3	I10	I20	Fu0	Po7	Be0	Er0	Fe8	0,8
13	Di3	In3	Se3	Ex0	Ps3	Pa0	Ce0	Ro9	Do8	Fc6	Zp5	Sp0	Ad0	I13	I29	Fu2	Po9	Be0	Er0	Fe4	0,8
14	Di4	In4	Se9	Ex0	Ps4	Pa0	Ce0	Ro2	Do6	Fc4	Zp0	Sp9	Ad0	I13	I20	Fu0	Po9	Be0	Er3	Fe1	0,8
15	Di0	In6	Se4	Ex0	Ps5	Pa2	Ce8	Ro1	Do9	Fc9	Zp5	Sp3	Ad0	I14	I20	Fu3	Po8	Be4	Er9	Fe0	0,8
16	Di0	In5	Se3	Ex6	Ps6	Pa9	Ce6	Ro0	Do1	Fc7	Zp0	Sp0	Ad7	I12	I20	Fu6	Po9	Be3	Er7	Fe9	0,8
17	Di4	In2	Se9	Ex0	Ps0	Pa1	Ce2	Ro9	Do5	Fc7	Zp8	Sp0	Ad4	I19	I28	Fu5	Po3	Be0	Er5	Fe0	0,8

Table 10: Several example statements of the fuzzy knowledge base (Source: Own work)

Special software was developed to simplify the interpretation of the results. The task of this software is to convert the information about the similarities into a similarity graph. This similarity graph can be seen in the next chapter. The resulting similarity graph is an opportunity to easily find other brownfields which are similar to a certain degree. The fuzzy knowledge base is analyzed in several ways in order to determine the ideal investment alternative based on the requirements formulated by the investor. The whole model can be found in Appendix 1 and also on the attached CD. The fuzzy logic software uses following equations and calculations to find intersections and similarities between fuzzy sets. Because there are twenty variables in the model the software calculates these intersections and similarities in twenty-dimensional space.

The similarity of two fuzzy sets can be mathematically described as:

$$s(n, V, W) = \min_{1 \leq j \leq n} \left(\max_{X_j} (\min(\mu_{Vj}(X_j), \mu_{Wj}(X_j))) \right)$$

where

$$\max_{X_j} \{\min(\mu_{Vj}(X_j), \mu_{Wj}(X_j))\}$$

represents the fuzzy intersection between V_j and W_j according to (Dohnal et al., 1996).

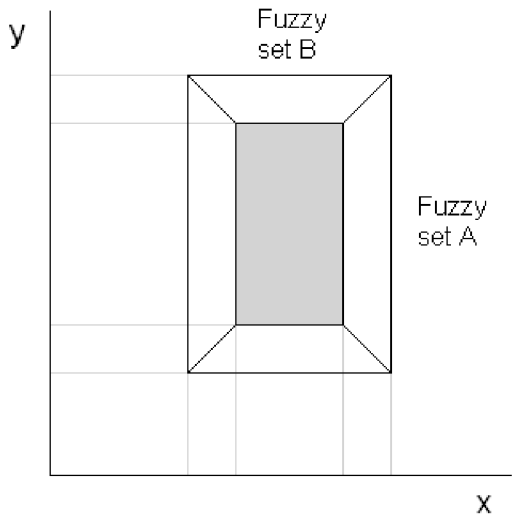

Figure 11: Intersection of two fuzzy sets in a two-dimensional space (Source: Own work)

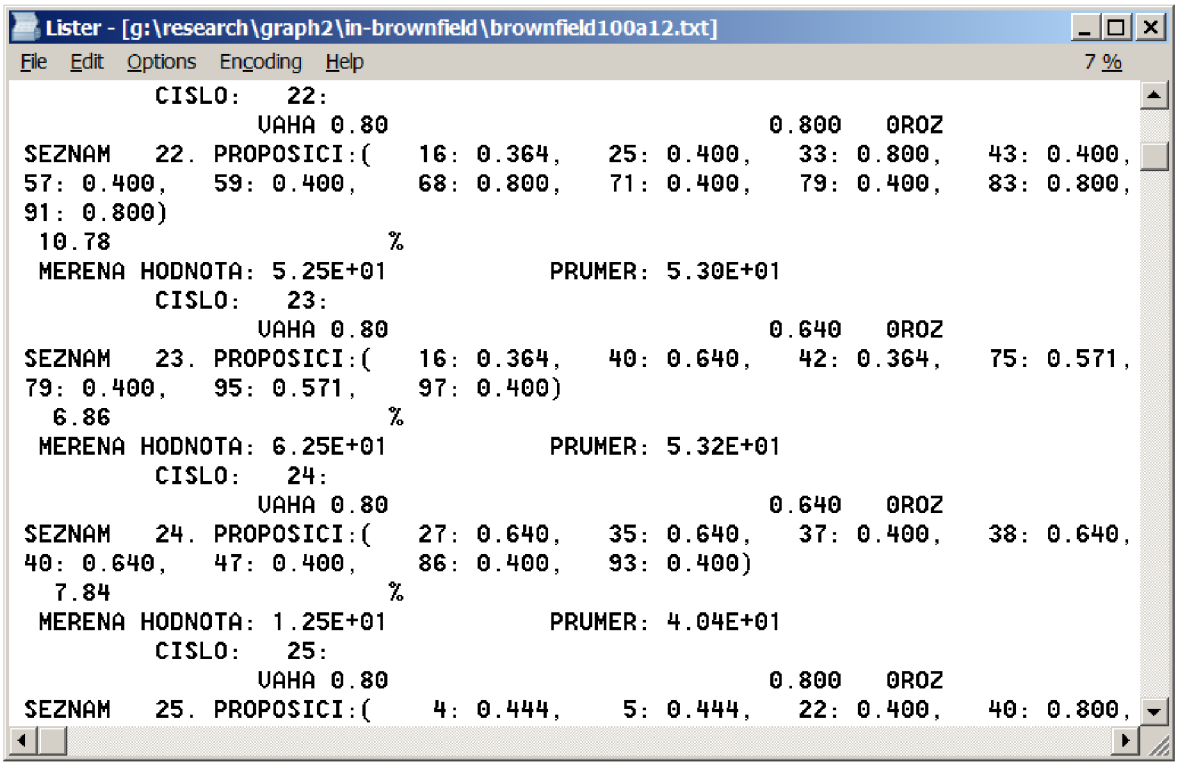

Figure 12: Output data of the fuzzy logic software containing information about calculated similarities between individual statements (Source: Own work)

It is also possible to use MATLAB and its Fuzzy logic toolbox for the implementation of a fuzzy model. The implementation of various economic models in MATLAB is described in (Dostál, 2008). After several tests it became apparent that the fuzzy model contains too many input variables and statements. The resulting model in MATLAB would be too complex and would not yield the desired results without adjustments to the model. The large number of statements in the knowledge base lead to conflicts in rules which the fuzzy toolbox generates. The model would have to be modified or divided in order to overcome this problem. Instead a special fuzzy logic software was used for the implementation of the model. The Fuzzy logic toolbox in MATLAB is designed primarily for models that use lower number of input variables and have fewer statements in the knowledge base. Following figure demonstrates a simple fuzzy model in the MATLAB fuzzy toolbox - its input are the four groups of variables described in this research.

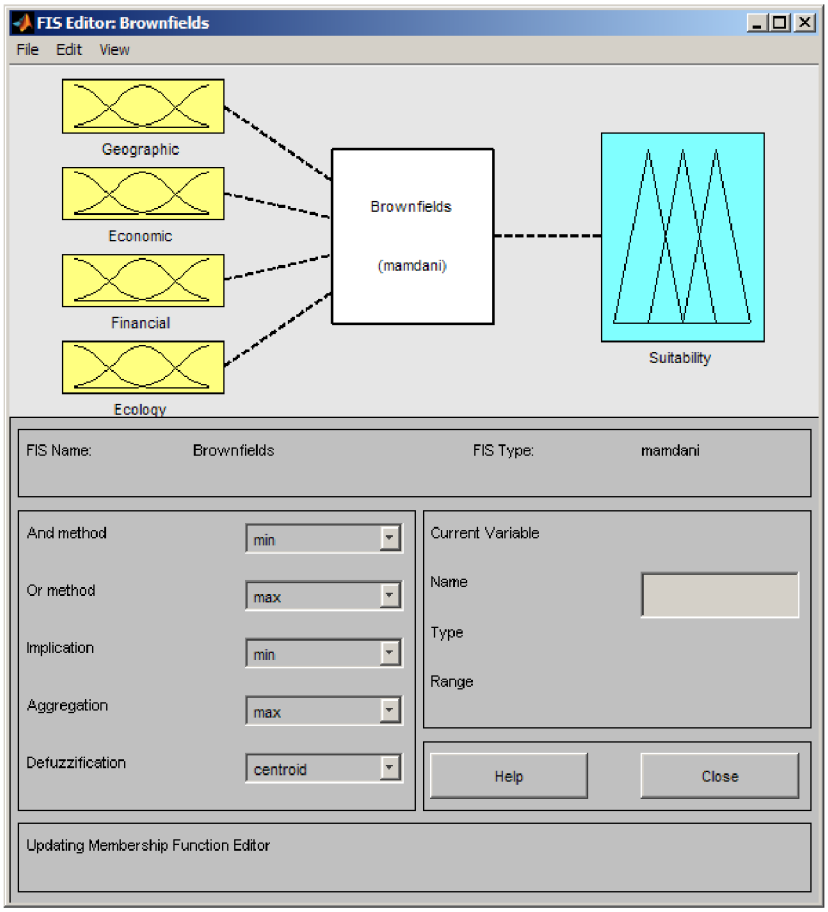

Figure 13: Sample fuzzy model implemented in the MATLAB Fuzzy Toolbox (Source: MATLAB)

3.8 Evaluation and interpretation of results

While the basic concept of fuzzy logic is easy to understand. The process becomes complex as large amount of information is loaded into the model. It is necessary to carefully interpret the results the fuzzy logic software calculates and outputs. A special application had to be developed – the task of this program is to filter the data and to look for certain patterns that indicate interesting information and relations. Thanks to this software is possible to quickly process the output data and to display only the information matching the requirements. It is also very helpful to visualize the results of the fuzzy software. A sophisticated and versatile graph drawing software called AiSee is used to visualize the relations and similarities between the statements in the knowledge base.

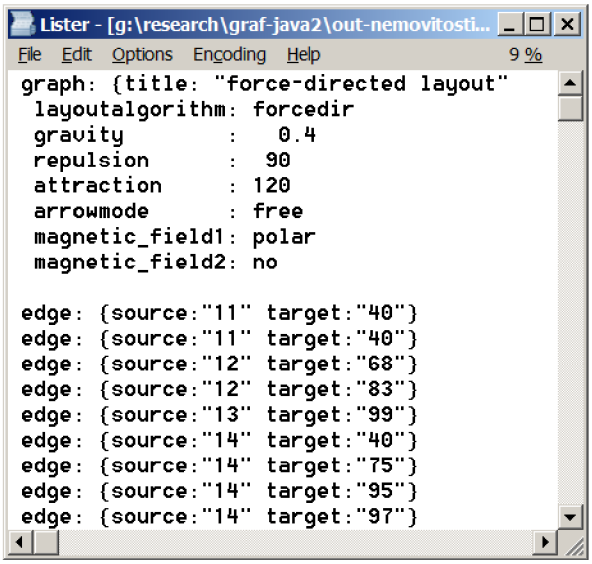

Figure 14: AiSee graph source file automatically generated from the results of the fuzzy model (Source: Own work)

The graph displays all statements in the knowledge base. Some statements are similar to each other and some are so different that they do not have any similarity to any other statement in the knowledge base. These findings are very useful and help to interpret the output of the fuzzy software. The software creates a large graph containing nodes and edges. This similarity is displayed in the graph as an edge between two nodes. In the center of the graph clusters of similar elements appear.

Large clusters and cores of clusters are closer to the center of the graph. Unique statements which are not similar to any other statements are displayed further away from the center of the graph. To visualize the results of the fuzzy model is very helpful and allows users to quickly get an overview of the data that was evaluated with the fuzzy model. The model is calculated many times with different settings which reflect the requirements of the investor. Each time the software outputs different results and also the resulting graphs look differently. Several similarity graphs are included in this chapter. Each calculation of the fuzzy model produces different results and of course different similarity graph. Dozens of similarity graphs were generated during the testing phase. Another software was created in order to filter only the strong similarities based on the user input.

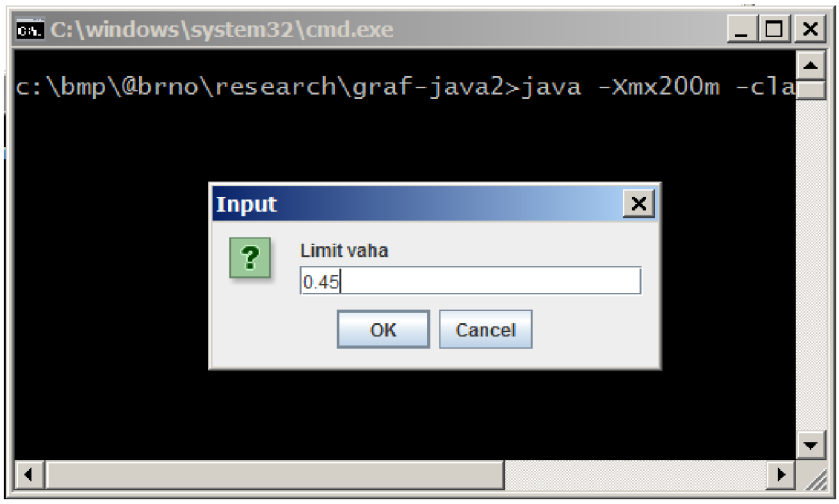

Figure 15: Software application for filtering relations with a set value (Source: Own work)

The graph drawing software does not include the option to set the strength of an edge in the graph so it was necessary to process the file with information about similarities so that only those similarities which fit the set criteria will be later displayed in the graph. The applications which were programmed for this process can be found on the attached CD. The developed applications facilitate the process of visualization and interpretation of the results tremendously. Without these applications and without the graph drawing software the processing and interpretation of the results would be very time consuming. Graphs generated with these applications are steadily being used also in other researches which involve complex fuzzy models such as the one in this research.

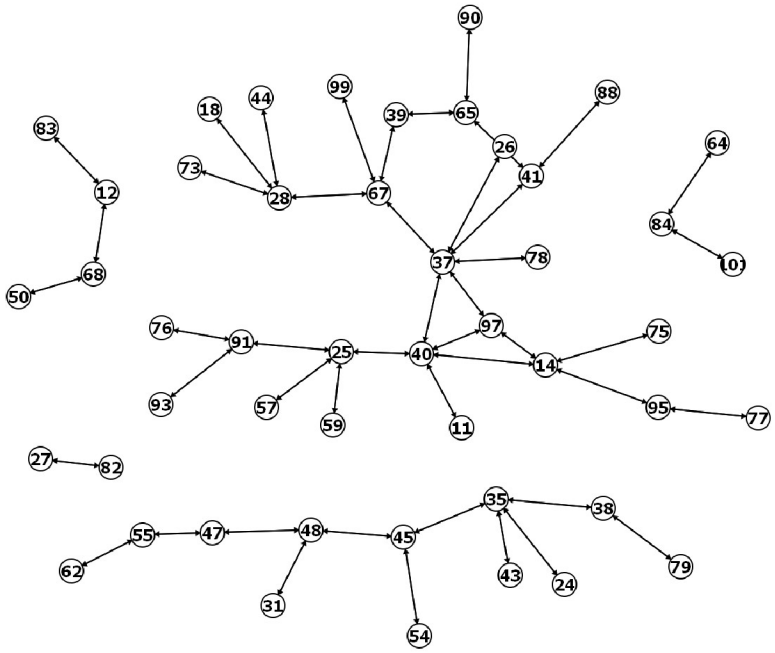

Figure 16: Similarity graph with stretching equal to 0 (economic and financial variables included) (Source: Own work)

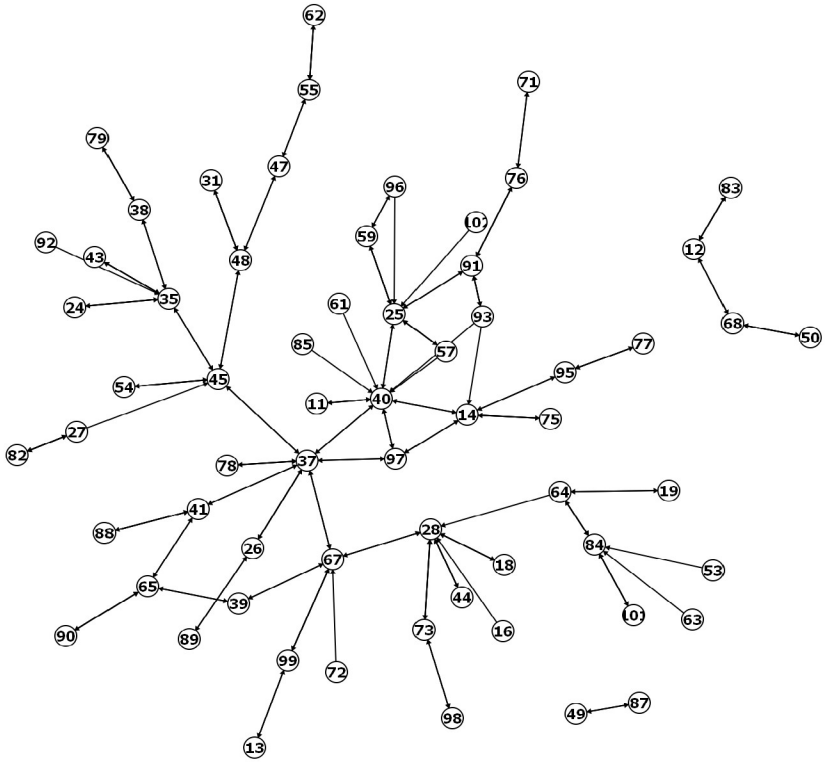

Figure 17: Similarity graph with stretching equal to 1 (economic and financial variables included) (Source: Own work)

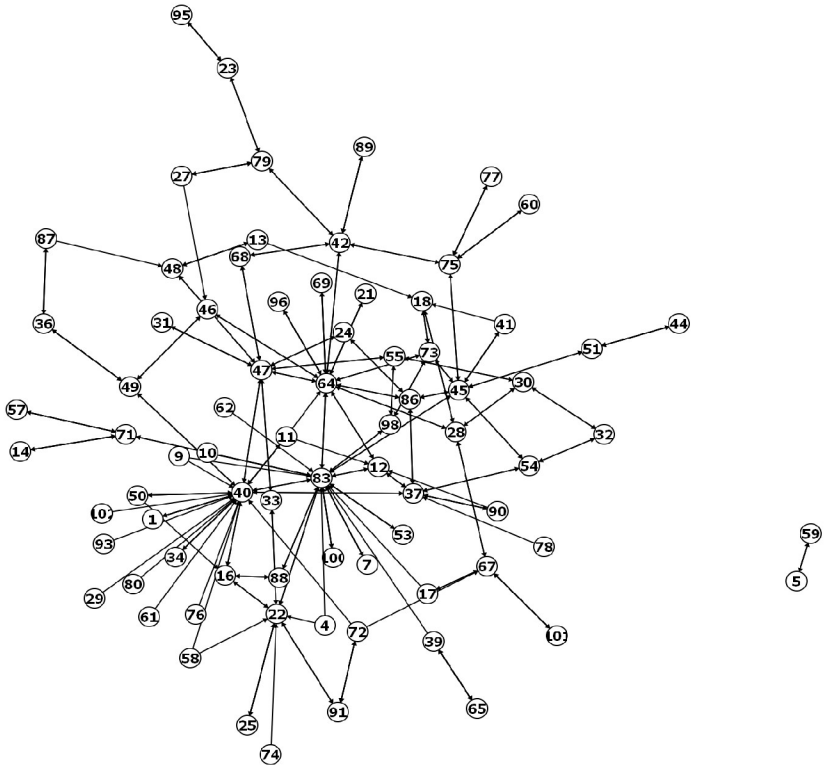

Figure 18: Similarity graph with stretching equal to 1 (economic and ecological variables included) (Source: Own work)

In order to visualize the multidimensional input data of the fuzzy knowledge base it is very useful to generate a 3D scatter plot in MATLAB software. However this visualization is not perfect as it is not possible to visualize this complex multidimensional input data only in three dimensions. The fuzzy knowledge base in this research has twenty variables so in order to truthfully visualize this data a twenty dimensional plot would have to be used. Even so it would be difficult to display individual statements as they contain variables with unknown value. A simplified matrix had to be generated for three sets of input criteria. This matrix had to be calculated using statistical methods in order to allow this simplified 3D visualization. The 3D scatter plot could also be used to easily filter out the best investment alternatives because they are the nearest to the edges of the plot. Slight disadvantage of this method is that it omits the unknown values of some criteria in the input knowledge base. In order to solve these limitations a comparison of results with results of other methods would have to be used for the correct representation of the results. The color and size of each point in the scatter plot can be set in order to represent its value relative to one of the axes of the plot.

Lister - [g:\research\matlab\3D-plot\brownfields.m]

File Edit Options Encoding Help 100 %

```
xdata=[58 62 58 67 67 48 62 58 70 57 51 54 70 46 55 45 57 44
33 36 47 42 52 42 43 68 40 62 64 31 53 42 64 53 25 56 40 29
62 20 42 56 54 61 70 56 58 54 46 57 37 70 66 37 36 49 65 59
47 45 35 56 70 39 41 45 58 33 44 80 51 61 56 51];

ydata=[73 70 73 88 63 40 63 48 45 80 49 26 41 26 28 44 62 44
26 65 89 52 40 45 39 40 48 66 46 25 44 75 34 50 7 56 72 75 3
52 76 61 65 25 66 67 42 90 72 67 37 37 46 40 42 52 28 56 30
73 67 100 35 0 40 60 23 43 50 46 41 52 27 53 59];

zdata=[70 65 53 60 53 68 58 85 75 83 71 72 65 38 67 71 35 36
38 44 63 55 48 51 29 59 52 49 54 27 26 58 79 51 28 51 46 23
73 45 24 50 43 58 63 13 59 50 88 68 45 59 25 37 43 35 53 78
10 51 54 92 31 55 61 40 75 43 31 81 60 56 41 40];

scatter3(xdata,ydata,zdata,55,'filled');
axis equal

title('Brownfields');
xlabel('Economic');
ylabel('Financial');
zlabel('Ecology');
```

Figure 19: MATLAB source file for generating a simplified 3D visualization of the fuzzy knowledge base (Source: Own work)

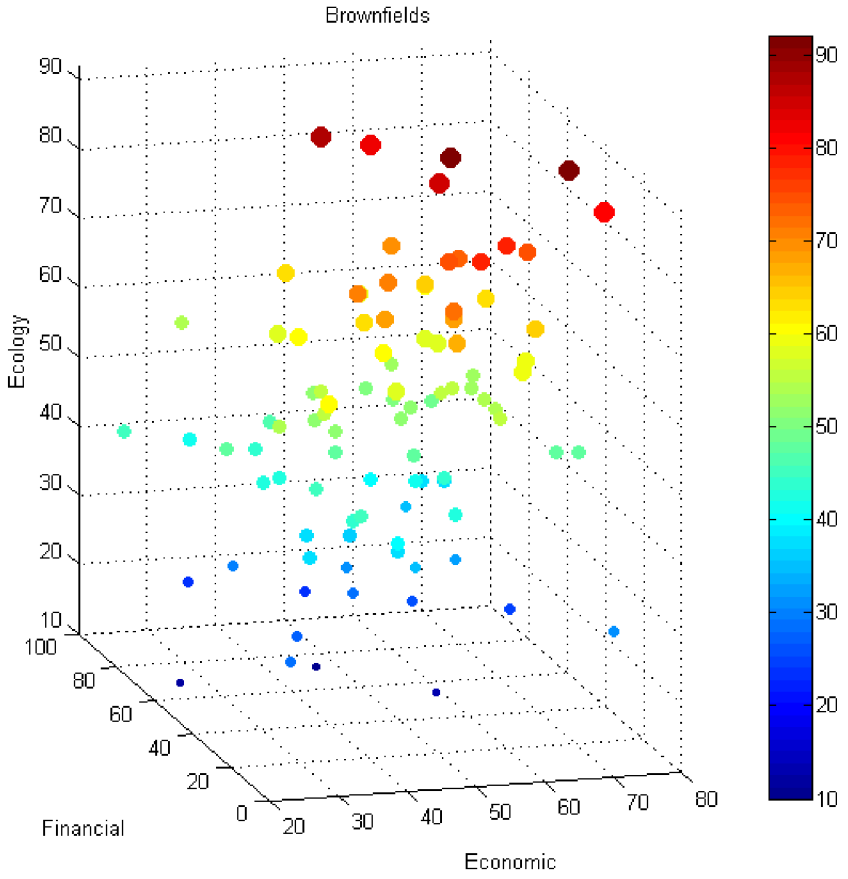

Figure 20: 3D scatter plot generated in MATLAB for average values of three groups of variables (Source: Own work)

3.9 Testing of the fuzzy model

Before the method is offered to investors it was necessary to perform thorough tests. Several applications for data collection, processing and for the interpretation of the results were created – it was also necessary to test these new applications. The objective of this research is to create a very flexible and robust method that can deal with the most situations and scenarios that will occur. The model has to work not only with a very small set of input data and few criteria but also with a large set of input data containing hundreds of real estates. It is possible to predict the requirements that the investors will have to a certain degree. But to be safe many different scenarios had to be simulated to ensure that there will not be difficulties and unanswered questions when real investors use this method to analyze and evaluate their set of investment alternatives. Fuzzy logic allows to work even with data that contains many unknown or uncertain variables. While testing the model it was necessary to supply test data that is similar to the data that will be supplied by the investors or collected from other sources.

There are several different methods how to test the validity of the results supplied by the fuzzy model. One of these methods is to manually check the input data and look for real estates that logically suit best the requirements of the investor. These real estates should be included in the reduced set outputted by the fuzzy software. However a situation can occur when the parameters of selection do not have same importance. For example the user can have special requirements related to ecological parameters. In this case it is possible to manually adjust the data and use weighted average. There has to be a similarity between the results obtained manually and the results produced by the fuzzy software to a certain degree. Another method how to test the validity of the results supplied by the fuzzy software is to put several ideal real estates into the input set of data. These real estates have to be included in the resulting set. There are several other methods how to test the validity of the results for example to use statistical methods etc. To ensure high reliability and flexibility of the model it is always necessary to perform several independent tests. Feedback of the investors during this process significantly improves the obtained results as some important details tend to be omitted frequently when the key requirements and objectives are initially formulated by the investor.

3.10 Fuzzy dialogue

Fuzzy logic software used in this research allows a type of dialogue with the fuzzy knowledge base. The application of fuzzy dialogue in accounting was researched in (Kába, 2009). The fuzzy dialogue in this research starts with a fuzzy model and a query formulated by the user. Based on the results obtained from the software a new query is formulated for the software. This second query returns a different result than the first query. The user who formulates the queries has an objective and modifies the queries based on the returned results so that the results are gradually refined toward the objective. Fuzzy dialogue is a powerful option to refine the information obtained from the fuzzy software.

The dialogue can be a series of two or more consecutive queries with the same model producing different results in each phase of the fuzzy dialogue. Fuzzy dialogue can be used in a combination with other methods to optimize the whole process of reducing the set of all available investment alternatives. If several different methods are used on the same fuzzy knowledge base, each method returns slightly different results but usually both methods output a certain percentage of same results - this part of the result can be considered as confirmed. The information which differs in the two obtained results is a good input for further analysis. The decision problem in this case is very complex so if a single method would be used it would not output ideal results. The usefulness of this research is in the utilization of a combination of methods which leads to significant improvement of the accuracy of the resulting recommendations for the investor. This research uses an approach based on the fuzzy model combined with simple statistical methods. Other methods could be used as well. For example genetic algorithms or artificial neural networks could also be used in combination with the fuzzy knowledge base. Different methods would yield different results which could be compared and would lead to additional conclusions which would be particularly useful in the interpretation of results. The use of these other approaches for this research problem will be covered in future research papers. Following figures and table show the definition of fuzzy query, results calculated by the fuzzy software and graphical representation of the center of gravity of two fuzzy sets.

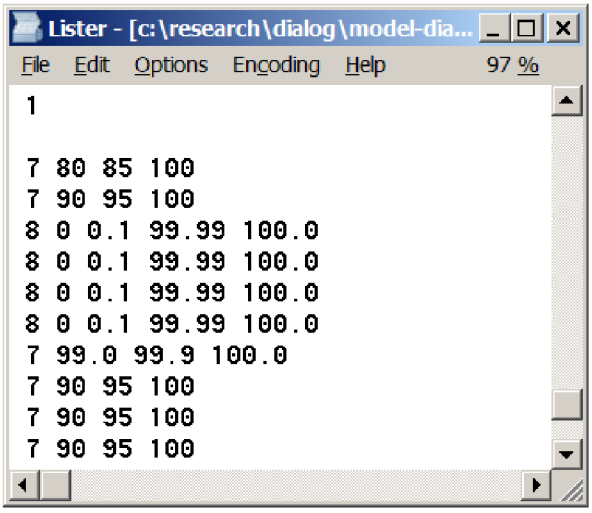

Figure 21: Sample query in a fuzzy dialogue (Source: Own work)

Query	Dependent variable	Fuzzy set	Center of gravity	Limiting variable
1	7	Ce6	0,67	1
1	7	Ce6	0,68	1
1	7	Ce2	0,05	8
2	8	Ro0	0,12	11
2	8	Ro8	0,15	9
2	8	Ro0	0,15	9
3	1	Di5	0,14	9
3	1	Di5	0,26	9
3	1	Di0	0,12	11
4	2	In9	0,28	7
4	2	In5	0,28	8

Table 11: Fuzzy queries and calculated results (Source: Own work)

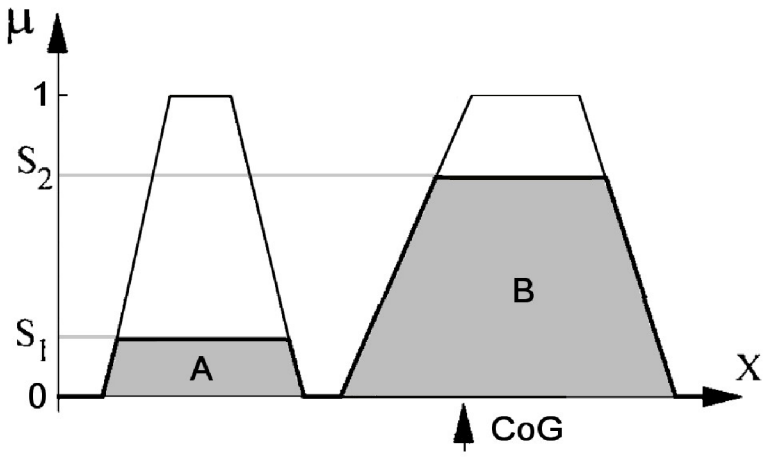

Figure 22: Center of gravity of two fuzzy sets (Source: Own work)

3.11 Implications and limitations of this research

It is also important to consider the limitations of this research. The fuzzy model outputs a result that needs to be interpreted and analyzed. The goal is not to recommend a single investment alternative to the investor but to analyze and evaluate the set of possible investments and to reduce this set to a much smaller set. For example if there will be several hundred possible investments the task of the designed fuzzy model is to reduce this set to a small set containing only about one or two dozen real estates which can later be thoroughly analyzed with conventional methods – for example financial indicators can be used in order to calculate the true value of the asset. This reduction is based on the criteria and requirements that are inputted into the model along with the investment alternatives recorded as statements in the fuzzy knowledge base. The processing speed of the computer is a major limitation in this research. The complex operations performed by the proprietary fuzzy logic software requires a lot of processing power. The processing of the model that contains more than four hundred real estates with twenty input criteria takes more than one hour.

If the input set is larger - then this set has to be reduced with the help of other methods before the fuzzy calculation is performed. For example real estates with too many unknown parameters can be removed from the input set. If there are too many unknown variables the statement tends to be similar to other statements which also have a lot of unknown variables. Therefore it is ideal not to include too many brownfield sites into the fuzzy model that have a large number of unknown variables. Another limitation is the complexity of the process. The process is too complex and cannot be performed by a single software application. Even with all the support software developed and ready to use it takes several days to perform all necessary phases of the process including collection of the input data, processing of the input data, creation of the model, fuzzy computation of different scenarios, interpretation of the results and formulation of the recommendations for the investor which include a reduced set of investment alternatives.

The current set of variables used in the model should suit the requirements of most investors who plan to redevelop a brownfield site. But it is clear that some investors may have different requirements and need to include a different set of variables which record the information important for their particular needs. The model is designed so it is easy to change the set of the input variables. The changes occur especially during the initial phases of the whole process – especially during the processing of the data. The fuzzy calculation and interpretation of the results stays the same even when the model uses a different set of variables.

Another limitation is that the fuzzy model requires the precise definition of requirements and objectives by the investor. Without precise objectives and requirements the fuzzy model cannot recommend the ideal investment alternatives. If an investor requires information about the investment alternatives that is not available in any database where it can be downloaded by the software written for this research it is necessary that the investor inputs this information into the fuzzy knowledge base. Newest notes and results related to this research are available online at http://www.dicts.info/files/fuzzy .

3.12 Proposed method

The proposed method consists of a sequence of following steps:

1. Definition of the objectives and requirements by the investor.
2. Initial analysis of the input from the investor and of available information about the investment alternatives.
3. Definition of the relevant parameters for the fuzzy model.
4. Data collection and processing.
5. Creation of the fuzzy model.
6. Thorough testing of the fuzzy model with different settings and scenarios and consultation with the investor.
7. Interpretation of the results.
8. Formulation of recommendations for the investor.

Each of these steps includes complex operations which are facilitated significantly by the software designed for this research. Particularly the processes of data collection and processing. Performing these tasks manually with the amount of information the fuzzy model is able to process would be very time consuming. The investor will certainly request at least one different criterion than those used for the initial fuzzy model in this research to be present in the fuzzy model. Therefore each process and software in this research was designed with flexibility in mind. Investors will be satisfied only if the proposed method is flexible enough for their individual needs.

3.13 Future research

This chapter contains information about future research papers and about continuation of this research in the future Several research papers about this research are now in the process of review in scientific journals or are ready for publication. The mentioned research papers deal with these topics. A simple chaos analysis of brownfield knowledge bases. Investment appraisal - Generic evaluation criteria for brownfields. Fuzzy logic modeling as a decision making support for investment appraisal. Economic, environmental and social benefits of brownfield redevelopment

This research will be continued and extended in the future because of its importance for investors and because brownfield redevelopment promotes sustainable development and smart growth. As soon as the investors request the use of this method for a real decision making problem. New selection criteria, requirements and objectives will be formulated by the investor. These expected new conditions will lead to modification and optimization of the process as it will be important to perform new currently unknown tasks. The new method is designed with flexibility in mind. The processes cannot be rigid but have to be very flexible in order to accommodate these new conditions. Recently two investors on an international business conference mentioned their need to efficiently evaluate large number of companies described by a large number of criteria. This evaluation would be used to calculate estimated market value of individual business companies. The method proposed in this research can of course be modified so it uses fuzzy knowledge base with different input information – as long as this input information consists of a matrix of measured or estimated values. This makes this research particularly useful as decision makers in different fields may be able to benefit from this research as well as the investors who are planning to redevelop brownfield sites. In the initial phases of this research it was considered to use not only the combination of fuzzy logic and statistical methods but also to use other methods like for example neural networks, genetic algorithms and other approaches. The comparison of several different results obtained with several completely different methods would surely lead to interesting conclusions and comparisons. However due to the complexity of this research incorporation of these additional methods will be researched in the future.

4 Contribution and utility of this research

The researched method facilitates the decision making process about real estate investment especially in cases where there are many possible alternative decisions and a large number of criteria. The fuzzy model will not recommend a single alternative but will reduce the large set of input real estates to a much smaller set of real estates based on the set criteria. It is then much easier for the decision makers to choose from this reduced set of alternative decisions. However the correctness of the results is strongly influenced by the quality of input information. If important details are not inputted into the model then the results may not be precise or may be skewed. It is therefore essential to input true and unbiased information and carefully create the set of all relevant criteria for the particular decision. Furthermore the qualified guesses bring a certain measure of uncertainty into the process as well.

Theoretical contribution of this research:

1) The creation of a complex method based on fuzzy logic that facilitates the decision making process about large investments - particularly brownfield redevelopment.
2) Findings leading to the optimization of complex processes related to decision making which include data collection, data processing, modeling, simulation, visualization and interpretation of results.
3) Definition of a hierarchy of generic evaluation criteria that can be used by investors in scenarios which include brownfield redevelopment.

Pedagogic contribution of this research:

1) The researched method will be presented to professors teaching subjects related to investing and investment evaluation.

Practical contribution of this research:

1) The creation of complex, robust and reliable method which facilitates the decision making process in cases which involve large amount of input information and a large set of alternative investment decisions. This new method will be presented to investors and offered as a service due to its complexity.
2) Creation of versatile software tools which are used for a variety of tasks in this research.
3) The researched method is very flexible and versatile - if a set of conditions is met this method can be used for other tasks in the real world which involve an evaluation of a large set of alternatives with a hierarchy of criteria.
4) Software created for this research is universal and has already been used in order to perform specific tasks in several other research projects. For example tasks such as the automated data collection, data extraction or data conversion are tasks frequently requested by fellow colleagues who perform these operations frequently in other research projects.
5) Software for automated processing and visualization of complex research data has already been used for the visualization of results in several published research papers by my colleagues. Creation of this software allows to interpret the complex results of the special fuzzy logic software more easily.

Conclusion

The main objective of this research was to design a robust and flexible method that facilitates the complex processes combining decision making, investment and brownfield redevelopment with the help of fuzzy logic and modeling. Due to a high degree of complexity of the researched problem it was necessary to think about the whole process and to try to modify and automate each individual process so that it would require minimal input from the investor. With a powerful decision support method such as this one the decision makers are able to process much larger amount of information and decide in a shorter time. Especially the process of data collection, analysis and processing can be optimized with the custom software written for these tasks.

Thanks to the special software created in this research a large amount of information about large number of investment alternatives can be collected in a short time. This data is then analyzed, processed and a fuzzy model is created. This model is then processed and a list of requirements and objectives defined by the investor is used to find the investment alternatives that match the set requirements. The possibility of customization of this set of relevant criteria is very important as different companies have different requirements. The model then reduces the set of possible investment alternatives and finds a small set of real estates that have the best combination of parameters based on the requirements. Unknown and imprecise information is not a problem for fuzzy logic. This makes this research particularly useful as almost no brownfield site or any other real estate is described precisely by the seller.

The proposed method is universal and with certain modifications can be used as a decision making support for other complex problems. Unlike other methods the proposed method has only a few requirements and limitations. After an extensive testing and optimization the new method will be offered as a service to real investors.

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Appendix

Appendix 1: Fuzzy model containing the brownfield knowledge base - first section contains the defition of the individual fuzzy sets for each evaluation criterium, second section contains the fuzzy statements describing each brownfield site.

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1 1.2 1.2

Di 10
Di0 8 0 20 80 100
Di1 8 0 2 8 10
Di2 8 5 10 15 20
Di3 8 15 20 25 30
Di4 8 25 30 35 40
Di5 8 35 40 45 50
Di6 8 45 50 55 60
Di7 8 55 60 65 70
Di8 8 65 70 75 80
Di9 8 70 80 100 150

In 10
In0 8 0 20 80 100
In1 8 0 2 8 10
In2 8 5 10 15 20
In3 8 15 20 25 30
In4 8 25 30 35 40
In5 8 35 40 45 50
In6 8 45 50 55 60
In7 8 55 60 65 70
In8 8 65 70 75 80
In9 8 70 80 100 150

Se 10
Se0 8 0 20 80 100
Se1 8 0 2 8 10
Se2 8 5 10 15 20
Se3 8 15 20 25 30
Se4 8 25 30 35 40
Se5 8 35 40 45 50
Se6 8 45 50 55 60
Se7 8 55 60 65 70
Se8 8 65 70 75 80
Se9 8 70 80 100 150

Ex 10
Ex0 8 0 20 80 100
Ex1 8 0 2 8 10
Ex2 8 5 10 15 20
Ex3 8 15 20 25 30
Ex4 8 25 30 35 40
Ex5 8 35 40 45 50
Ex6 8 45 50 55 60
Ex7 8 55 60 65 70
Ex8 8 65 70 75 80
Ex9 8 70 80 100 150

Ps 10
Ps0 8 0 20 80 100
Ps1 8 0 2 8 10
Ps2 8 5 10 15 20
Ps3 8 15 20 25 30
Ps4 8 25 30 35 40
Ps5 8 35 40 45 50
Ps6 8 45 50 55 60
Ps7 8 55 60 65 70
Ps8 8 65 70 75 80
Ps9 8 70 80 100 150

Pa 10
Pa0 8 0 20 80 100
Pa1 8 0 2 8 10
Pa2 8 5 10 15 20
Pa3 8 15 20 25 30
Pa4 8 25 30 35 40
Pa5 8 35 40 45 50
Pa6 8 45 50 55 60
Pa7 8 55 60 65 70
Pa8 8 65 70 75 80
Pa9 8 70 80 100 150

Ce 10
Ce0 8 0 20 80 100
Ce1 8 0 2 8 10
Ce2 8 5 10 15 20
Ce3 8 15 20 25 30
Ce4 8 25 30 35 40
Ce5 8 35 40 45 50
Ce6 8 45 50 55 60
Ce7 8 55 60 65 70
Ce8 8 65 70 75 80
Ce9 8 70 80 100 150

Ro 10
Ro0 8 0 20 80 100
Ro1 8 0 2 8 10
Ro2 8 5 10 15 20
Ro3 8 15 20 25 30
Ro4 8 25 30 35 40
Ro5 8 35 40 45 50
Ro6 8 45 50 55 60
Ro7 8 55 60 65 70
Ro8 8 65 70 75 80
Ro9 8 70 80 100 150

Do 10
Do0 8 0 20 80 100
Do1 8 0 2 8 10
Do2 8 5 10 15 20
Do3 8 15 20 25 30
Do4 8 25 30 35 40
Do5 8 35 40 45 50
Do6 8 45 50 55 60
Do7 8 55 60 65 70
Do8 8 65 70 75 80
Do9 8 70 80 100 150

Fc 10
Fc0 8 0 20 80 100
Fc1 8 0 2 8 10
Fc2 8 5 10 15 20
Fc3 8 15 20 25 30
Fc4 8 25 30 35 40
Fc5 8 35 40 45 50
Fc6 8 45 50 55 60
Fc7 8 55 60 65 70
Fc8 8 65 70 75 80
Fc9 8 70 80 100 150

Zp 10
Zp0 8 0 20 80 100
Zp1 8 0 2 8 10
Zp2 8 5 10 15 20
Zp3 8 15 20 25 30
Zp4 8 25 30 35 40
Zp5 8 35 40 45 50
Zp6 8 45 50 55 60
Zp7 8 55 60 65 70
Zp8 8 65 70 75 80
Zp9 8 70 80 100 150

Sp 10
Sp0 8 0 20 80 100
Sp1 8 0 2 8 10
Sp2 8 5 10 15 20
Sp3 8 15 20 25 30
Sp4 8 25 30 35 40
Sp5 8 35 40 45 50
Sp6 8 45 50 55 60
Sp7 8 55 60 65 70
Sp8 8 65 70 75 80
Sp9 8 70 80 100 150

Ad 10
Ad0 8 0 20 80 100
Ad1 8 0 2 8 10
Ad2 8 5 10 15 20
Ad3 8 15 20 25 30
Ad4 8 25 30 35 40
Ad5 8 35 40 45 50
Ad6 8 45 50 55 60
Ad7 8 55 60 65 70
Ad8 8 65 70 75 80
Ad9 8 70 80 100 150

I1 10
I10 8 0 20 80 100
I11 8 0 2 8 10
I12 8 5 10 15 20
I13 8 15 20 25 30
I14 8 25 30 35 40
I15 8 35 40 45 50
I16 8 45 50 55 60
I17 8 55 60 65 70
I18 8 65 70 75 80
I19 8 70 80 100 150

I2 10
I20 8 0 20 80 100
I21 8 0 2 8 10
I22 8 5 10 15 20
I23 8 15 20 25 30
I24 8 25 30 35 40
I25 8 35 40 45 50
I26 8 45 50 55 60
I27 8 55 60 65 70
I28 8 65 70 75 80
I29 8 70 80 100 150

Fu 10
Fu0 8 0 20 80 100
Fu1 8 0 2 8 10
Fu2 8 5 10 15 20
Fu3 8 15 20 25 30
Fu4 8 25 30 35 40
Fu5 8 35 40 45 50
Fu6 8 45 50 55 60
Fu7 8 55 60 65 70
Fu8 8 65 70 75 80
Fu9 8 70 80 100 150

Po 10
Po0 8 0 20 80 100
Po1 8 0 2 8 10
Po2 8 5 10 15 20
Po3 8 15 20 25 30
Po4 8 25 30 35 40
Po5 8 35 40 45 50
Po6 8 45 50 55 60
Po7 8 55 60 65 70
Po8 8 65 70 75 80
Po9 8 70 80 100 150

Be 10
Be0 8 0 20 80 100
Be1 8 0 2 8 10
Be2 8 5 10 15 20
Be3 8 15 20 25 30
Be4 8 25 30 35 40
Be5 8 35 40 45 50
Be6 8 45 50 55 60
Be7 8 55 60 65 70
Be8 8 65 70 75 80
Be9 8 70 80 100 150

Er 10
Er0 8 0 20 80 100
Er1 8 0 2 8 10
Er2 8 5 10 15 20
Er3 8 15 20 25 30
Er4 8 25 30 35 40
Er5 8 35 40 45 50
Er6 8 45 50 55 60
Er7 8 55 60 65 70
Er8 8 65 70 75 80
Er9 8 70 80 100 150

Fe 10
Fe0 8 0 20 80 100
Fe1 8 0 2 8 10
Fe2 8 5 10 15 20
Fe3 8 15 20 25 30
Fe4 8 25 30 35 40
Fe5 8 35 40 45 50
Fe6 8 45 50 55 60
Fe7 8 55 60 65 70
Fe8 8 65 70 75 80
Fe9 8 70 80 100 150

Di3 In9 Se7 Ex7 Ps8 Pa9 Ce9 Ro8 Do4 Fc7 Zp7 Sp5 Ad7 I19 I29 Fu6 Po9 Be7 Er7 Fe9 1
Di4 In4 Se7 Ex8 Ps6 Pa7 Ce9 Ro5 Do5 Fc8 Zp6 Sp8 Ad8 I19 I27 Fu8 Po6 Be5 Er9 Fe9 1
Di2 In8 Se9 Ex4 Ps8 Pa8 Ce7 Ro9 Do2 Fc5 Zp9 Sp7 Ad9 I17 I29 Fu6 Po8 Be4 Er8 Fe5 1
Di6 In5 Se8 Ex8 Ps7 Pa8 Ce7 Ro9 Do5 Fc5 Zp9 Sp9 Ad9 I17 I29 Fu9 Po6 Be8 Er7 Fe7 1

Di5 In9 Se8 Ex9 Ps9 Pa9 Ce8 Ro8 Do4 Fc9 Zp7 Sp9 Ad4 I18 I27 Fu9 Po6 Be7 Er7 Fe5 1
Di3 In8 Se5 Ex8 Ps3 Pa2 Ce3 Ro9 Do4 Fc9 Zp5 Sp5 Ad6 I13 I21 Fu9 Po6 Be7 Er9 Fe8 1
Di5 In8 Se7 Ex9 Ps6 Pa7 Ce9 Ro7 Do6 Fc5 Zp9 Sp6 Ad7 I18 I29 Fu5 Po4 Be9 Er5 Fe9 1
Di3 In5 Se9 Ex9 Ps5 Pa8 Ce9 Ro9 Do4 Fc5 Zp5 Sp8 Ad9 I14 I27 Fu3 Po9 Be6 Er9 Fe9 1
Di5 In9 Se8 Ex2 Ps6 Pa8 Ce9 Ro9 Do6 Fc6 Zp9 Sp7 Ad4 I17 I24 Fu7 Po9 Be9 Er6 Fe9 1
Di6 In9 Se6 Ex6 Ps9 Pa9 Ce5 Ro9 Do5 Fc8 Zp5 Sp6 Ad9 I18 I29 Fu9 Po8 Be9 Er9 Fe9 1
Di0 In7 Se0 Ex0 Ps9 Pa0 Ce3 Ro6 Do4 Fc7 Zp0 Sp8 Ad1 I19 I20 Fu0 Po9 Be0 Er6 Fe0 0.8
Di4 In7 Se8 Ex6 Ps0 Pa4 Ce4 Ro7 Do0 Fc0 Zp3 Sp9 Ad3 I10 I20 Fu0 Po7 Be0 Er0 Fe8 0.8
Di3 In3 Se3 Ex0 Ps3 Pa0 Ce0 Ro9 Do8 Fc6 Zp5 Sp0 Ad0 I13 I29 Fu2 Po9 Be0 Er0 Fe4 0.8
Di4 In4 Se9 Ex0 Ps4 Pa0 Ce0 Ro2 Do6 Fc4 Zp0 Sp9 Ad0 I13 I20 Fu0 Po9 Be0 Er3 Fe1 0.8
Di0 In6 Se4 Ex0 Ps5 Pa2 Ce8 Ro1 Do9 Fc9 Zp5 Sp3 Ad0 I14 I20 Fu3 Po8 Be4 Er9 Fe0 0.8
Di0 In5 Se3 Ex6 Ps6 Pa9 Ce6 Ro0 Do1 Fc7 Zp0 Sp0 Ad7 I12 I20 Fu6 Po9 Be3 Er7 Fe9 0.8
Di4 In2 Se9 Ex0 Ps0 Pa1 Ce2 Ro9 Do5 Fc7 Zp8 Sp0 Ad4 I19 I28 Fu5 Po3 Be0 Er5 Fe0 0.8
Di5 In6 Se7 Ex3 Ps7 Pa0 Ce6 Ro7 Do0 Fc0 Zp5 Sp2 Ad9 I10 I22 Fu2 Po0 Be6 Er2 Fe0 0.8
Di6 In3 Se8 Ex9 Ps0 Pa0 Ce5 Ro5 Do0 Fc7 Zp3 Sp4 Ad9 I10 I23 Fu1 Po9 Be3 Er5 Fe4 0.8
Di8 In8 Se9 Ex4 Ps9 Pa5 Ce9 Ro5 Do4 Fc2 Zp1 Sp1 Ad0 I10 I20 Fu4 Po4 Be7 Er7 Fe0 0.8
Di9 In0 Se3 Ex9 Ps9 Pa0 Ce0 Ro9 Do0 Fc9 Zp4 Sp1 Ad2 I19 I24 Fu2 Po3 Be3 Er6 Fe8 0.8
Di0 In0 Se0 Ex1 Ps3 Pa6 Ce6 Ro7 Do0 Fc0 Zp9 Sp8 Ad2 I13 I26 Fu1 Po0 Be0 Er0 Fe9 0.8
Di0 In0 Se8 Ex4 Ps2 Pa3 Ce7 Ro2 Do0 Fc6 Zp7 Sp0 Ad5 I19 I29 Fu1 Po5 Be9 Er0 Fe0 0.8
Di0 In0 Se0 Ex1 Ps4 Pa0 Ce2 Ro4 Do6 Fc2 Zp0 Sp0 Ad6 I19 I29 Fu9 Po8 Be2 Er4 Fe6 0.8
Di9 In4 Se3 Ex0 Ps7 Pa3 Ce7 Ro8 Do4 Fc0 Zp0 Sp8 Ad0 I19 I24 Fu0 Po3 Be0 Er1 Fe8 0.8
Di9 In5 Se0 Ex0 Ps0 Pa0 Ce0 Ro3 Do4 Fc9 Zp3 Sp1 Ad0 I10 I20 Fu3 Po0 Be4 Er4 Fe0 0.8
Di8 In3 Se4 Ex8 Ps0 Pa2 Ce0 Ro4 Do0 Fc0 Zp0 Sp0 Ad1 I18 I29 Fu9 Po1 Be9 Er3 Fe6 0.8
Di1 In8 Se5 Ex2 Ps7 Pa9 Ce0 Ro7 Do2 Fc9 Zp0 Sp2 Ad9 I10 I20 Fu0 Po7 Be0 Er0 Fe0 0.8
Di3 In9 Se7 Ex0 Ps8 Pa0 Ce2 Ro0 Do1 Fc7 Zp9 Sp6 Ad6 I12 I20 Fu9 Po7 Be6 Er5 Fe0 0.8
Di5 In5 Se5 Ex0 Ps9 Pa3 Ce9 Ro6 Do2 Fc0 Zp0 Sp0 Ad2 I11 I27 Fu8 Po0 Be2 Er9 Fe5 0.8
Di2 In3 Se8 Ex1 Ps9 Pa6 Ce0 Ro4 Do9 Fc2 Zp0 Sp0 Ad2 I15 I24 Fu9 Po6 Be3 Er5 Fe8 0.8
Di0 In9 Se0 Ex9 Ps9 Pa6 Ce9 Ro0 Do2 Fc3 Zp5 Sp0 Ad1 I13 I20 Fu9 Po0 Be1 Er0 Fe6 0.8
Di0 In1 Se7 Ex8 Ps5 Pa6 Ce0 Ro0 Do8 Fc6 Zp9 Sp0 Ad0 I12 I28 Fu3 Po5 Be5 Er0 Fe9 0.8
Di4 In0 Se6 Ex0 Ps3 Pa9 Ce6 Ro1 Do2 Fc8 Zp6 Sp3 Ad3 I14 I27 Fu8 Po0 Be5 Er5 Fe7 0.8
Di7 In0 Se3 Ex2 Ps6 Pa8 Ce0 Ro4 Do0 Fc0 Zp9 Sp0 Ad6 I19 I20 Fu0 Po5 Be0 Er8 Fe3 0.8
Di0 In0 Se0 Ex2 Ps0 Pa1 Ce7 Ro5 Do9 Fc8 Zp5 Sp0 Ad4 I19 I23 Fu3 Po9 Be0 Er3 Fe0 0.8
Di3 In0 Se0 Ex0 Ps4 Pa2 Ce3 Ro0 Do5 Fc0 Zp0 Sp0 Ad1 I15 I20 Fu0 Po0 Be1 Er2 Fe7 0.8
Di6 In0 Se8 Ex9 Ps1 Pa8 Ce0 Ro4 Do0 Fc0 Zp9 Sp4 Ad5 I10 I20 Fu5 Po5 Be0 Er0 Fe1 0.8
Di0 In0 Se8 Ex3 Ps3 Pa1 Ce1 Ro9 Do0 Fc2 Zp0 Sp5 Ad8 I10 I28 Fu0 Po3 Be9 Er0 Fe0 0.8
Di0 In5 Se8 Ex0 Ps7 Pa6 Ce0 Ro0 Do0 Fc0 Zp7 Sp0 Ad2 I10 I25 Fu5 Po9 Be0 Er0 Fe8 0.8
Di7 In3 Se9 Ex5 Ps0 Pa6 Ce0 Ro9 Do4 Fc5 Zp4 Sp0 Ad0 I16 I25 Fu0 Po6 Be6 Er0 Fe5 0.8
Di0 In1 Se0 Ex0 Ps0 Pa7 Ce7 Ro1 Do0 Fc0 Zp0 Sp1 Ad2 I10 I20 Fu1 Po3 Be0 Er0 Fe0 0.8
Di4 In5 Se1 Ex0 Ps7 Pa4 Ce5 Ro0 Do2 Fc3 Zp9 Sp9 Ad5 I19 I25 Fu0 Po3 Be0 Er9 Fe5 0.8
Di3 In4 Se6 Ex1 Ps8 Pa3 Ce5 Ro0 Do1 Fc0 Zp9 Sp2 Ad8 I17 I28 Fu0 Po3 Be9 Er2 Fe6 0.8
Di8 In0 Se9 Ex3 Ps0 Pa9 Ce2 Ro0 Do0 Fc4 Zp0 Sp4 Ad0 I10 I27 Fu9 Po0 Be0 Er1 Fe5 0.8
Di0 In4 Se5 Ex7 Ps5 Pa9 Ce0 Ro4 Do9 Fc9 Zp3 Sp6 Ad3 I11 I20 Fu9 Po1 Be7 Er0 Fe0 0.8
Di0 In3 Se2 Ex1 Ps9 Pa3 Ce1 Ro5 Do0 Fc0 Zp0 Sp8 Ad2 I15 I21 Fu0 Po0 Be0 Er5 Fe0 0.8
Di7 In9 Se0 Ex0 Ps1 Pa0 Ce1 Ro0 Do9 Fc0 Zp6 Sp0 Ad2 I14 I20 Fu8 Po9 Be8 Er5 Fe3 0.8
Di0 In5 Se9 Ex2 Ps5 Pa9 Ce8 Ro5 Do8 Fc9 Zp0 Sp0 Ad4 I19 I22 Fu1 Po0 Be6 Er3 Fe7 0.8
Di0 In9 Se1 Ex5 Ps2 Pa7 Ce6 Ro9 Do0 Fc0 Zp0 Sp4 Ad3 I16 I23 Fu8 Po0 Be2 Er9 Fe8 0.8
Di5 In2 Se3 Ex1 Ps6 Pa9 Ce0 Ro2 Do0 Fc3 Zp9 Sp3 Ad5 I15 I21 Fu2 Po4 Be9 Er0 Fe0 0.8
Di8 In2 Se0 Ex0 Ps2 Pa0 Ce0 Ro5 Do2 Fc9 Zp5 Sp1 Ad2 I14 I21 Fu0 Po6 Be1 Er7 Fe7 0.8
Di3 In0 Se2 Ex1 Ps7 Pa1 Ce9 Ro0 Do7 Fc8 Zp1 Sp7 Ad5 I16 I26 Fu0 Po0 Be0 Er7 Fe9 0.8
Di8 In4 Se6 Ex1 Ps0 Pa4 Ce0 Ro1 Do0 Fc0 Zp4 Sp0 Ad0 I19 I27 Fu9 Po9 Be0 Er1 Fe0 0.8
Di6 In9 Se0 Ex3 Ps5 Pa6 Ce0 Ro0 Do2 Fc1 Zp7 Sp9 Ad0 I15 I20 Fu9 Po0 Be1 Er0 Fe5 0.8

Di8 In8 Se9 Ex5 Ps7 Pa0 Ce9 Ro1 Do8 Fc0 Zp3 Sp8 Ad0 I10 I29 Fu5 Po0 Be9 Er3 Fe4 0.8
Di0 In0 Se0 Ex9 Ps1 Pa7 Ce0 Ro8 Do3 Fc4 Zp9 Sp0 Ad2 I10 I20 Fu4 Po0 Be0 Er8 Fe1 0.8
Di0 In7 Se0 Ex9 Ps4 Pa0 Ce6 Ro9 Do2 Fc7 Zp8 Sp7 Ad2 I19 I28 Fu0 Po7 Be9 Er3 Fe0 0.8
Di4 In1 Se0 Ex4 Ps0 Pa1 Ce7 Ro8 Do5 Fc9 Zp0 Sp0 Ad2 I19 I20 Fu9 Po7 Be6 Er9 Fe5 0.8
Di5 In5 Se0 Ex0 Ps7 Pa8 Ce8 Ro1 Do0 Fc9 Zp7 Sp5 Ad1 I13 I26 Fu9 Po2 Be0 Er2 Fe2 0.8
Di9 In0 Se0 Ex2 Ps9 Pa9 Ce3 Ro1 Do9 Fc8 Zp9 Sp6 Ad0 I19 I20 Fu0 Po9 Be5 Er4 Fe8 0.8
Di3 In1 Se9 Ex0 Ps0 Pa3 Ce4 Ro9 Do0 Fc1 Zp8 Sp8 Ad6 I10 I20 Fu9 Po1 Be9 Er0 Fe6 0.8
Di0 In9 Se0 Ex2 Ps9 Pa9 Ce7 Ro7 Do9 Fc2 Zp2 Sp2 Ad0 I10 I27 Fu0 Po0 Be8 Er0 Fe9 0.8
Di0 In0 Se7 Ex5 Ps4 Pa1 Ce0 Ro0 Do0 Fc9 Zp3 Sp0 Ad7 I14 I20 Fu1 Po0 Be0 Er6 Fe9 0.8
Di0 In0 Se2 Ex2 Ps0 Pa4 Ce0 Ro0 Do3 Fc0 Zp3 Sp6 Ad0 I16 I20 Fu3 Po0 Be0 Er9 Fe1 0.8
Di1 In5 Se5 Ex9 Ps4 Pa4 Ce4 Ro7 Do9 Fc9 Zp5 Sp9 Ad8 I10 I20 Fu2 Po6 Be7 Er4 Fe8 0.8
Di3 In3 Se0 Ex5 Ps5 Pa0 Ce0 Ro8 Do0 Fc0 Zp7 Sp0 Ad0 I14 I28 Fu2 Po0 Be2 Er4 Fe3 0.8
Di9 In0 Se0 Ex0 Ps9 Pa6 Ce0 Ro0 Do4 Fc4 Zp0 Sp0 Ad4 I10 I22 Fu8 Po2 Be9 Er4 Fe2 0.8
Di6 In8 Se5 Ex7 Ps9 Pa9 Ce1 Ro4 Do0 Fc9 Zp3 Sp3 Ad2 I19 I24 Fu8 Po1 Be3 Er0 Fe9 0.8
Di2 In4 Se7 Ex4 Ps0 Pa8 Ce0 Ro0 Do5 Fc9 Zp2 Sp6 Ad2 I13 I25 Fu5 Po1 Be6 Er0 Fe5 0.8
Di6 In9 Se3 Ex0 Ps0 Pa7 Ce7 Ro0 Do0 Fc4 Zp9 Sp9 Ad9 I18 I26 Fu1 Po9 Be8 Er0 Fe1 0.8
Di1 In0 Se0 Ex3 Ps4 Pa0 Ce3 Ro0 Do2 Fc9 Zp9 Sp9 Ad5 I13 I20 Fu2 Po8 Be0 Er0 Fe0 0.8
Di2 In9 Se2 Ex9 Ps5 Pa9 Ce0 Ro6 Do2 Fc0 Zp0 Sp3 Ad9 I17 I24 Fu4 Po2 Be5 Er0 Fe0 0.8
Di7 In0 Se9 Ex3 Ps9 Pa3 Ce5 Ro9 Do9 Fc0 Zp8 Sp7 Ad3 I11 I25 Fu8 Po1 Be6 Er8 Fe0 0.8
Di8 In3 Se3 Ex9 Ps0 Pa4 Ce0 Ro1 Do5 Fc0 Zp0 Sp0 Ad8 I10 I22 Fu9 Po2 Be3 Er1 Fe0 0.8
Di8 In0 Se6 Ex6 Ps9 Pa1 Ce9 Ro1 Do1 Fc0 Zp9 Sp9 Ad8 I10 I27 Fu1 Po9 Be6 Er2 Fe0 0.8
Di3 In0 Se0 Ex9 Ps3 Pa0 Ce0 Ro1 Do0 Fc9 Zp8 Sp8 Ad7 I18 I25 Fu8 Po2 Be3 Er0 Fe8 0.8
Di9 In0 Se5 Ex6 Ps4 Pa0 Ce0 Ro6 Do4 Fc0 Zp3 Sp1 Ad0 I10 I25 Fu7 Po3 Be0 Er3 Fe9 0.8
Di0 In3 Se0 Ex2 Ps0 Pa6 Ce7 Ro0 Do8 Fc5 Zp8 Sp0 Ad4 I16 I22 Fu6 Po0 Be9 Er2 Fe5 0.8
Di0 In9 Se0 Ex8 Ps6 Pa6 Ce5 Ro9 Do1 Fc1 Zp9 Sp5 Ad9 I18 I24 Fu9 Po0 Be0 Er2 Fe0 0.8
Di2 In2 Se0 Ex0 Ps0 Pa9 Ce4 Ro3 Do3 Fc7 Zp4 Sp9 Ad9 I19 I21 Fu9 Po7 Be1 Er9 Fe0 0.8
Di5 In9 Se8 Ex0 Ps0 Pa0 Ce5 Ro3 Do2 Fc0 Zp2 Sp8 Ad0 I10 I20 Fu9 Po6 Be8 Er2 Fe7 0.8
Di0 In2 Se7 Ex2 Ps2 Pa4 Ce0 Ro7 Do6 Fc0 Zp0 Sp0 Ad3 I19 I21 Fu2 Po0 Be9 Er0 Fe0 0.8
Di7 In4 Se5 Ex7 Ps0 Pa1 Ce9 Ro8 Do9 Fc0 Zp2 Sp0 Ad0 I10 I20 Fu0 Po1 Be5 Er2 Fe6 0.8
Di8 In7 Se7 Ex9 Ps0 Pa0 Ce1 Ro2 Do3 Fc6 Zp9 Sp4 Ad0 I15 I20 Fu0 Po0 Be9 Er0 Fe3 0.8
Di0 In0 Se9 Ex0 Ps3 Pa3 Ce3 Ro4 Do6 Fc0 Zp0 Sp5 Ad8 I19 I27 Fu2 Po7 Be0 Er0 Fe0 0.8
Di5 In9 Se5 Ex0 Ps2 Pa8 Ce0 Ro5 Do7 Fc7 Zp0 Sp2 Ad4 I10 I21 Fu0 Po8 Be0 Er4 Fe2 0.8
Di5 In9 Se9 Ex0 Ps2 Pa2 Ce5 Ro8 Do0 Fc0 Zp5 Sp7 Ad4 I15 I20 Fu5 Po9 Be0 Er6 Fe8 0.8
Di1 In9 Se3 Ex8 Ps3 Pa7 Ce0 Ro2 Do4 Fc7 Zp3 Sp2 Ad6 I17 I26 Fu3 Po0 Be5 Er7 Fe2 0.8
Di5 In9 Se0 Ex0 Ps0 Pa1 Ce0 Ro9 Do4 Fc1 Zp3 Sp7 Ad5 I16 I28 Fu2 Po9 Be1 Er2 Fe0 0.8
Di1 In8 Se9 Ex2 Ps8 Pa3 Ce0 Ro0 Do0 Fc8 Zp9 Sp8 Ad8 I10 I20 Fu1 Po9 Be7 Er8 Fe9 0.8
Di3 In0 Se8 Ex2 Ps1 Pa0 Ce4 Ro4 Do0 Fc0 Zp7 Sp6 Ad6 I17 I24 Fu6 Po4 Be9 Er0 Fe7 0.8
Di0 In1 Se4 Ex2 Ps3 Pa0 Ce0 Ro3 Do7 Fc0 Zp9 Sp7 Ad0 I13 I24 Fu0 Po9 Be1 Er4 Fe9 0.8
Di2 In9 Se7 Ex0 Ps7 Pa9 Ce6 Ro9 Do3 Fc9 Zp5 Sp2 Ad6 I17 I20 Fu4 Po2 Be8 Er3 Fe5 0.8
Di0 In1 Se6 Ex1 Ps0 Pa0 Ce0 Ro1 Do6 Fc0 Zp0 Sp9 Ad6 I10 I24 Fu9 Po4 Be9 Er2 Fe3 0.8
Di7 In3 Se6 Ex0 Ps0 Pa2 Ce9 Ro0 Do5 Fc9 Zp3 Sp7 Ad1 I18 I25 Fu0 Po0 Be3 Er5 Fe9 0.8
Di6 In0 Se0 Ex9 Ps8 Pa9 Ce0 Ro1 Do0 Fc5 Zp6 Sp8 Ad2 I10 I20 Fu5 Po7 Be4 Er6 Fe3 0.8
Di3 In6 Se9 Ex0 Ps2 Pa9 Ce3 Ro7 Do0 Fc1 Zp6 Sp0 Ad0 I19 I23 Fu5 Po1 Be0 Er9 Fe0 0.8
Di7 In4 Se8 Ex8 Ps6 Pa0 Ce3 Ro7 Do9 Fc6 Zp6 Sp4 Ad0 I10 I28 Fu2 Po5 Be4 Er9 Fe3 0.8
Di8 In1 Se2 Ex0 Ps7 Pa9 Ce8 Ro8 Do0 Fc7 Zp8 Sp9 Ad6 I19 I26 Fu9 Po4 Be0 Er0 Fe5 0.8
Di3 In6 Se9 Ex9 Ps0 Pa9 Ce9 Ro7 Do9 Fc4 Zp0 Sp0 Ad5 I15 I20 Fu4 Po4 Be2 Er0 Fe2 0.8
Di2 In3 Se1 Ex1 Ps0 Pa0 Ce9 Ro0 Do5 Fc1 Zp9 Sp8 Ad9 I19 I20 Fu4 Po9 Be6 Er2 Fe0 0.8

8 9 10 11 12 13 14 15 16 7
variables = 20; statements = 102

Appendix 2: Sample result of the calculations performed by the fuzzy logic software. The interpretation of this complex data would be difficult without the special software developed in this research.

```
Brownfield-100a#
ZIVE PROMENNE:
 8  9 10 11 12 13 14 15 16  7 % :  1.00
ROZTAZENI:  0
          NOVA KONSISTENCE
          CISLO:    1:
          VAHA 1.00       0.000   0ROZ
SEZNAM    1. PROPOSICI:PRAZDNY     CISLO:    2:
          VAHA 1.00       0.000   0ROZ
SEZNAM    2. PROPOSICI:PRAZDNY     CISLO:    3:
          VAHA 1.00       0.000   0ROZ
SEZNAM    3. PROPOSICI:PRAZDNY     CISLO:    4:
          VAHA 1.00       0.000   0ROZ
SEZNAM    4. PROPOSICI:PRAZDNY     CISLO:    5:
          VAHA 1.00       0.000   0ROZ
SEZNAM    5. PROPOSICI:PRAZDNY     CISLO:    6:
          VAHA 1.00       0.000   0ROZ
SEZNAM    6. PROPOSICI:PRAZDNY     CISLO:    7:
          VAHA 1.00       0.000   0ROZ
SEZNAM    7. PROPOSICI:PRAZDNY     CISLO:    8:
          VAHA 1.00       0.000   0ROZ
SEZNAM    8. PROPOSICI:PRAZDNY     CISLO:    9:
          VAHA 1.00       0.000   0ROZ
SEZNAM    9. PROPOSICI:PRAZDNY     CISLO:   10:
          VAHA 1.00       0.000   0ROZ
SEZNAM   10. PROPOSICI:PRAZDNY     CISLO:   11:
          VAHA 0.80       0.571   0ROZ
SEZNAM   11. PROPOSICI:(   40: 0.571)
 0.98    %
 MERENA HODNOTA: 2.25E+01PRUMER: 5.00E+01       CISLO:   12:
          VAHA 0.80       0.400   0ROZ
SEZNAM   12. PROPOSICI:(   68: 0.400,   83: 0.364)
 1.96    %
 MERENA HODNOTA: 3.25E+01PRUMER: 5.00E+01       CISLO:   13:
          VAHA 0.80       0.000   0ROZ
SEZNAM   13. PROPOSICI:PRAZDNY     CISLO:   14:
          VAHA 0.80       0.640   0ROZ
SEZNAM   14. PROPOSICI:(   40: 0.640,   75: 0.400,   95: 0.571,   97: 0.400)
 3.92    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   15:
          VAHA 0.80       0.000   0ROZ
SEZNAM   15. PROPOSICI:PRAZDNY     CISLO:   16:
          VAHA 0.80       0.000   0ROZ
SEZNAM   16. PROPOSICI:PRAZDNY     CISLO:   17:
          VAHA 0.80       0.000   0ROZ
SEZNAM   17. PROPOSICI:PRAZDNY     CISLO:   18:
          VAHA 0.80       0.640   0ROZ
SEZNAM   18. PROPOSICI:(   28: 0.640)
 0.98    %
 MERENA HODNOTA: 5.25E+01PRUMER: 5.00E+01       CISLO:   19:
          VAHA 0.80       0.000   0ROZ
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SEZNAM  19. PROPOSICI:PRAZDNY    CISLO:  20:
        VAHA 0.80       0.000  0ROZ
SEZNAM  20. PROPOSICI:PRAZDNY    CISLO:  21:
        VAHA 0.80       0.000  0ROZ
SEZNAM  21. PROPOSICI:PRAZDNY    CISLO:  22:
        VAHA 0.80       0.000  0ROZ
SEZNAM  22. PROPOSICI:PRAZDNY    CISLO:  23:
        VAHA 0.80       0.000  0ROZ
SEZNAM  23. PROPOSICI:PRAZDNY    CISLO:  24:
        VAHA 0.80       0.640  0ROZ
SEZNAM  24. PROPOSICI:(  35: 0.640)
 0.98   %
 MERENA HODNOTA: 1.25E+01PRUMER: 5.00E+01       CISLO:  25:
        VAHA 0.80       0.400  0ROZ
SEZNAM  25. PROPOSICI:(  40: 0.400,  57: 0.400,  59: 0.400,  91: 0.364)
 3.92   %
 MERENA HODNOTA: 6.25E+01PRUMER: 5.32E+01       CISLO:  26:
        VAHA 0.80       0.364  0ROZ
SEZNAM  26. PROPOSICI:(  37: 0.364)
 0.98   %
 MERENA HODNOTA: 5.00E+01PRUMER: 2.25E+01       CISLO:  27:
        VAHA 0.80       0.364  0ROZ
SEZNAM  27. PROPOSICI:(  82: 0.364)
 0.98   %
 MERENA HODNOTA: 5.00E+01PRUMER: 4.25E+01       CISLO:  28:
        VAHA 0.80       0.640  0ROZ
SEZNAM  28. PROPOSICI:(  18: 0.640,  44: 0.533,  67: 0.400,  73: 0.400)
 3.92   %
 MERENA HODNOTA: 5.00E+01PRUMER: 4.88E+01       CISLO:  29:
        VAHA 0.80       0.000  0ROZ
SEZNAM  29. PROPOSICI:PRAZDNY    CISLO:  30:
        VAHA 0.80       0.000  0ROZ
SEZNAM  30. PROPOSICI:PRAZDNY    CISLO:  31:
        VAHA 0.80       0.364  0ROZ
SEZNAM  31. PROPOSICI:(  48: 0.364)
 0.98   %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+00       CISLO:  32:
        VAHA 0.80       0.000  0ROZ
SEZNAM  32. PROPOSICI:PRAZDNY    CISLO:  33:
        VAHA 0.80       0.000  0ROZ
SEZNAM  33. PROPOSICI:PRAZDNY    CISLO:  34:
        VAHA 0.80       0.000  0ROZ
SEZNAM  34. PROPOSICI:PRAZDNY    CISLO:  35:
        VAHA 0.80       0.640  0ROZ
SEZNAM  35. PROPOSICI:(  24: 0.640,  38: 0.400,  43: 0.400,  45: 0.640)
 3.92   %
 MERENA HODNOTA: 5.00E+01PRUMER: 2.55E+01       CISLO:  36:
        VAHA 0.80       0.000  0ROZ
SEZNAM  36. PROPOSICI:PRAZDNY    CISLO:  37:
        VAHA 0.80       0.571  0ROZ
SEZNAM  37. PROPOSICI:(  26: 0.364,  40: 0.571,  41: 0.364,  45: 0.364,  67: 0.364,  78: 0.364,  97:
0.364)
 6.86   %
 MERENA HODNOTA: 2.25E+01PRUMER: 4.50E+01       CISLO:  38:
        VAHA 0.80       0.400  0ROZ
SEZNAM  38. PROPOSICI:(  35: 0.400,  79: 0.400)
```

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 1.96    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.63E+01       CISLO:   39:
         VAHA 0.80       0.364   0ROZ
SEZNAM   39. PROPOSICI:(   65: 0.364,   67: 0.364)
 1.96    %
 MERENA HODNOTA: 5.00E+00PRUMER: 5.00E+01       CISLO:   40:
         VAHA 0.80       0.640   0ROZ
SEZNAM   40. PROPOSICI:(   11: 0.571,   14: 0.640,   25: 0.400,   37: 0.571,   97: 0.364)
 4.90    %
 MERENA HODNOTA: 5.00E+01PRUMER: 3.96E+01       CISLO:   41:
         VAHA 0.80       0.400   0ROZ
SEZNAM   41. PROPOSICI:(   37: 0.364,   65: 0.400,   88: 0.400)
 2.94    %
 MERENA HODNOTA: 5.00E+01PRUMER: 3.88E+01       CISLO:   42:
         VAHA 0.80       0.000   0ROZ
SEZNAM   42. PROPOSICI:PRAZDNY    CISLO:   43:
         VAHA 0.80       0.400   0ROZ
SEZNAM   43. PROPOSICI:(   35: 0.400)
 0.98    %
 MERENA HODNOTA: 4.25E+01PRUMER: 5.00E+01       CISLO:   44:
         VAHA 0.80       0.533   0ROZ
SEZNAM   44. PROPOSICI:(   28: 0.533)
 0.98    %
 MERENA HODNOTA: 4.25E+01PRUMER: 5.00E+01       CISLO:   45:
         VAHA 0.80       0.640   0ROZ
SEZNAM   45. PROPOSICI:(   35: 0.640,   37: 0.364,   48: 0.533,   54: 0.364)
 3.92    %
 MERENA HODNOTA: 1.25E+01PRUMER: 3.21E+01       CISLO:   46:
         VAHA 0.80       0.000   0ROZ
SEZNAM   46. PROPOSICI:PRAZDNY    CISLO:   47:
         VAHA 0.80       0.364   0ROZ
SEZNAM   47. PROPOSICI:(   48: 0.364,   55: 0.364)
 1.96    %
 MERENA HODNOTA: 5.00E+00PRUMER: 2.75E+01       CISLO:   48:
         VAHA 0.80       0.533   0ROZ
SEZNAM   48. PROPOSICI:(   31: 0.364,   45: 0.533,   47: 0.364)
 2.94    %
 MERENA HODNOTA: 5.00E+00PRUMER: 2.12E+01       CISLO:   49:
         VAHA 0.80       0.000   0ROZ
SEZNAM   49. PROPOSICI:PRAZDNY    CISLO:   50:
         VAHA 0.80       0.400   0ROZ
SEZNAM   50. PROPOSICI:(   68: 0.400)
 0.98    %
 MERENA HODNOTA: 5.25E+01PRUMER: 5.00E+01       CISLO:   51:
         VAHA 0.80       0.000   0ROZ
SEZNAM   51. PROPOSICI:PRAZDNY    CISLO:   52:
         VAHA 0.80       0.000   0ROZ
SEZNAM   52. PROPOSICI:PRAZDNY    CISLO:   53:
         VAHA 0.80       0.000   0ROZ
SEZNAM   53. PROPOSICI:PRAZDNY    CISLO:   54:
         VAHA 0.80       0.364   0ROZ
SEZNAM   54. PROPOSICI:(   45: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 1.25E+01       CISLO:   55:
         VAHA 0.80       0.400   0ROZ
SEZNAM   55. PROPOSICI:(   47: 0.364,   62: 0.400)
```

```
 1.96    %
 MERENA HODNOTA: 5.00E+01PRUMER: 1.94E+01      CISLO:   56:
         VAHA 0.80       0.000   0ROZ
SEZNAM   56. PROPOSICI:PRAZDNY    CISLO:   57:
         VAHA 0.80       0.400   0ROZ
SEZNAM   57. PROPOSICI:(   25: 0.400)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 6.25E+01      CISLO:   58:
         VAHA 0.80       0.000   0ROZ
SEZNAM   58. PROPOSICI:PRAZDNY    CISLO:   59:
         VAHA 0.80       0.400   0ROZ
SEZNAM   59. PROPOSICI:(   25: 0.400)
 0.98    %
 MERENA HODNOTA: 6.25E+01PRUMER: 6.25E+01      CISLO:   60:
         VAHA 0.80       0.000   0ROZ
SEZNAM   60. PROPOSICI:PRAZDNY    CISLO:   61:
         VAHA 0.80       0.000   0ROZ
SEZNAM   61. PROPOSICI:PRAZDNY    CISLO:   62:
         VAHA 0.80       0.400   0ROZ
SEZNAM   62. PROPOSICI:(   55: 0.400)
 0.98    %
 MERENA HODNOTA: 3.25E+01PRUMER: 5.00E+01      CISLO:   63:
         VAHA 0.80       0.000   0ROZ
SEZNAM   63. PROPOSICI:PRAZDNY    CISLO:   64:
         VAHA 0.80       0.364   0ROZ
SEZNAM   64. PROPOSICI:(   84: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 1.02E+02      CISLO:   65:
         VAHA 0.80       0.400   0ROZ
SEZNAM   65. PROPOSICI:(   39: 0.364,   41: 0.400,   90: 0.364)
 2.94    %
 MERENA HODNOTA: 5.00E+01PRUMER: 3.55E+01      CISLO:   66:
         VAHA 0.80       0.000   0ROZ
SEZNAM   66. PROPOSICI:PRAZDNY    CISLO:   67:
         VAHA 0.80       0.400   0ROZ
SEZNAM   67. PROPOSICI:(   28: 0.400,   37: 0.364,   39: 0.364,   99: 0.400)
 3.92    %
 MERENA HODNOTA: 5.00E+01PRUMER: 2.55E+01      CISLO:   68:
         VAHA 0.80       0.400   0ROZ
SEZNAM   68. PROPOSICI:(   12: 0.400,   50: 0.400)
 1.96    %
 MERENA HODNOTA: 5.00E+01PRUMER: 4.25E+01      CISLO:   69:
         VAHA 0.80       0.000   0ROZ
SEZNAM   69. PROPOSICI:PRAZDNY    CISLO:   70:
         VAHA 0.80       0.000   0ROZ
SEZNAM   70. PROPOSICI:PRAZDNY    CISLO:   71:
         VAHA 0.80       0.000   0ROZ
SEZNAM   71. PROPOSICI:PRAZDNY    CISLO:   72:
         VAHA 0.80       0.000   0ROZ
SEZNAM   72. PROPOSICI:PRAZDNY    CISLO:   73:
         VAHA 0.80       0.400   0ROZ
SEZNAM   73. PROPOSICI:(   28: 0.400)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01      CISLO:   74:
         VAHA 0.80       0.000   0ROZ
SEZNAM   74. PROPOSICI:PRAZDNY    CISLO:   75:
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          VAHA 0.80       0.400   0ROZ
SEZNAM   75. PROPOSICI:(   14: 0.400)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   76:
          VAHA 0.80       0.364   0ROZ
SEZNAM   76. PROPOSICI:(   91: 0.364)
 0.98    %
 MERENA HODNOTA: 1.02E+02PRUMER: 5.00E+01       CISLO:   77:
          VAHA 0.80       0.400   0ROZ
SEZNAM   77. PROPOSICI:(   95: 0.400)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   78:
          VAHA 0.80       0.364   0ROZ
SEZNAM   78. PROPOSICI:(   37: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 2.25E+01       CISLO:   79:
          VAHA 0.80       0.400   0ROZ
SEZNAM   79. PROPOSICI:(   38: 0.400)
 0.98    %
 MERENA HODNOTA: 6.25E+01PRUMER: 5.00E+01       CISLO:   80:
          VAHA 0.80       0.000   0ROZ
SEZNAM   80. PROPOSICI:PRAZDNY    CISLO:   81:
          VAHA 0.80       0.000   0ROZ
SEZNAM   81. PROPOSICI:PRAZDNY    CISLO:   82:
          VAHA 0.80       0.364   0ROZ
SEZNAM   82. PROPOSICI:(   27: 0.364)
 0.98    %
 MERENA HODNOTA: 4.25E+01PRUMER: 5.00E+01       CISLO:   83:
          VAHA 0.80       0.364   0ROZ
SEZNAM   83. PROPOSICI:(   12: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 3.25E+01       CISLO:   84:
          VAHA 0.80       0.400   0ROZ
SEZNAM   84. PROPOSICI:(   64: 0.364,  101: 0.400)
 1.96    %
 MERENA HODNOTA: 1.02E+02PRUMER: 7.72E+01       CISLO:   85:
          VAHA 0.80       0.000   0ROZ
SEZNAM   85. PROPOSICI:PRAZDNY    CISLO:   86:
          VAHA 0.80       0.000   0ROZ
SEZNAM   86. PROPOSICI:PRAZDNY    CISLO:   87:
          VAHA 0.80       0.000   0ROZ
SEZNAM   87. PROPOSICI:PRAZDNY    CISLO:   88:
          VAHA 0.80       0.400   0ROZ
SEZNAM   88. PROPOSICI:(   41: 0.400)
 0.98    %
 MERENA HODNOTA: 4.25E+01PRUMER: 5.00E+01       CISLO:   89:
          VAHA 0.80       0.000   0ROZ
SEZNAM   89. PROPOSICI:PRAZDNY    CISLO:   90:
          VAHA 0.80       0.364   0ROZ
SEZNAM   90. PROPOSICI:(   65: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   91:
          VAHA 0.80       0.364   0ROZ
SEZNAM   91. PROPOSICI:(   25: 0.364,   76: 0.364,   93: 0.364)
 2.94    %
 MERENA HODNOTA: 5.00E+01PRUMER: 7.15E+01       CISLO:   92:
```

```
          VAHA 0.80       0.000   0ROZ
SEZNAM   92. PROPOSICI:PRAZDNY     CISLO:   93:
          VAHA 0.80       0.364   0ROZ
SEZNAM   93. PROPOSICI:(   91: 0.364)
 0.98    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   94:
          VAHA 0.80       0.000   0ROZ
SEZNAM   94. PROPOSICI:PRAZDNY     CISLO:   95:
          VAHA 0.80       0.571   0ROZ
SEZNAM   95. PROPOSICI:(   14: 0.571,   77: 0.400)
 1.96    %
 MERENA HODNOTA: 5.00E+01PRUMER: 5.00E+01       CISLO:   96:
          VAHA 0.80       0.000   0ROZ
SEZNAM   96. PROPOSICI:PRAZDNY     CISLO:   97:
          VAHA 0.80       0.400   0ROZ
SEZNAM   97. PROPOSICI:(   14: 0.400,   37: 0.364,   40: 0.364)
 2.94    %
 MERENA HODNOTA: 5.00E+01PRUMER: 4.11E+01       CISLO:   98:
          VAHA 0.80       0.000   0ROZ
SEZNAM   98. PROPOSICI:PRAZDNY     CISLO:   99:
          VAHA 0.80       0.400   0ROZ
SEZNAM   99. PROPOSICI:(   67: 0.400)
 0.98    %
 MERENA HODNOTA: 2.25E+01PRUMER: 5.00E+01       CISLO:  100:
          VAHA 0.80       0.000   0ROZ
SEZNAM  100. PROPOSICI:PRAZDNY     CISLO:  101:
          VAHA 0.80       0.400   0ROZ
SEZNAM  101. PROPOSICI:(   84: 0.400)
 0.98    %
 MERENA HODNOTA: 1.02E+02PRUMER: 1.02E+02       CISLO:  102:
          VAHA 0.80       0.000   0ROZ
SEZNAM  102. PROPOSICI:PRAZDNY      STARA KONSISTENCE
          PROPOSICE CISLO:    1  0
0
          PROPOSICE CISLO:    2  0
0
          PROPOSICE CISLO:    3  0
0
          PROPOSICE CISLO:    4  0
0
          PROPOSICE CISLO:    5  0
0
          PROPOSICE CISLO:    6  0
0
          PROPOSICE CISLO:    7  0
0
          PROPOSICE CISLO:    8  0
0
          PROPOSICE CISLO:    9  0
0
          PROPOSICE CISLO:   10  0
0
          PROPOSICE CISLO:   11   Ce0      8:          0.00        20.00       80.00       100.00 |  0.571   40 0.57 13
          0           0.98
          50.00:    0.57       50.00:    0.57       NEDEF.:....          NEDEF.:....          50.00:    0.57       50.00:
          0.57
```

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        50.00:  0.57    50.00:  0.57
        50.00:  0.57    50.00:  0.57
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  12  Ce9   8:      70.00   80.00   100.00  150.00 |  0.400   30 0.36 14
84 0.40  8  Ce7   8:      55.00   60.00   65.00   70.00 |  0.400   25 0.40  8  59 0.40  8  Ce0              8:
        0.00    20.00   80.00   100.00 |  0.400   68 0.40 13  83 0.36 15
        0       5.88
        71.31:  0.40    NEDEF.:....     NEDEF.:....     NEDEF.:....     73.12:  0.40    73.12:
        0.40
        73.12:  0.40    73.12:  0.40
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     PROPOSICE CISLO:  13  0
0
        PROPOSICE CISLO:  14  Ce0   8:      0.00    20.00   80.00   100.00 |  0.640   40 0.64  8
75 0.40  9  95 0.57  8  97 0.40 10
        0       3.92
        50.00:  0.64    50.00:  0.64    50.00:  0.64    NEDEF.:....     50.00:  0.64    50.00:
        0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    NEDEF.:....
        NEDEF.:....     NEDEF.:....     PROPOSICE CISLO:  15  0
0
        PROPOSICE CISLO:  16  0
0
        PROPOSICE CISLO:  17  0
0
        PROPOSICE CISLO:  18  Ce0   8:      0.00    20.00   80.00   100.00 |  0.640   28 0.64  9
        0       0.98
        50.00:  0.64    50.00:  0.64    50.00:  0.64    NEDEF.:....     50.00:  0.64    50.00:
        0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  19  0
0
        PROPOSICE CISLO:  20  Ce3   8:      15.00   20.00   25.00   30.00 |  0.364   37 0.36 11
        0       0.98
        22.50:  0.36    NEDEF.:....     NEDEF.:....     NEDEF.:....     22.50:  0.36    22.50:
        0.36
        22.50:  0.36    22.50:  0.36
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  21  0
0
        PROPOSICE CISLO:  22  0
0
        PROPOSICE CISLO:  23  0
0
        PROPOSICE CISLO:  24  Ce0   8:      0.00    20.00   80.00   100.00 |  0.640   35 0.64 10
        0       0.98
```

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        50.00:  0.64    50.00:  0.64    50.00:  0.64    NEDEF.:....     50.00:  0.64    50.00:
        0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    50.00:  0.64
        50.00:  0.64    NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  25  Ce9   8:      70.00   80.00   100.00  150.00 |  0.364   96 0.36 13
102 0.36 10  Ce7   8:      55.00   60.00   65.00   70.00 |  0.400   59 0.40  9  Ce3   8:
        15.00   20.00   25.00   30.00 |  0.364   98 0.36 10  Ce4   8:      25.00   30.00   35.00
        40.00 |  0.400   12 0.40  8  62 0.36 10  Ce0   8:      0.00    20.00   80.00   100.00 |  0.400   40
0.40 15  57 0.40  9  91 0.36 16
        0       8.82
        68.80:  0.40    NEDEF.:....     NEDEF.:....     NEDEF.:....     64.64:  0.40    64.64:
        0.40
        64.64:  0.40    64.64:  0.40
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     PROPOSICE CISLO:  26  Ce3   8:      15.00   20.00
        25.00   30.00 |  0.364   37 0.36 12
        0       0.98
        22.50:  0.36    NEDEF.:....     NEDEF.:....     NEDEF.:....     22.50:  0.36    22.50:
        0.36
        22.50:  0.36    22.50:  0.36
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  27  Ce5   8:      35.00   40.00   45.00   50.00 |  0.364   82 0.36 13
        0       0.98
        42.50:  0.36    NEDEF.:....     NEDEF.:....     NEDEF.:....     42.50:  0.36    42.50:
        0.36
        42.50:  0.36    42.50:  0.36
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     0
        PROPOSICE CISLO:  28  Ce5   8:      35.00   40.00   45.00   50.00 |  0.533   44 0.53 13
Ce0   8:      0.00    20.00   80.00   100.00 |  0.400   67 0.40  8  73 0.40  8  Ce6   8:      45.00
        50.00   55.00   60.00 |  0.640   18 0.64  9
        0       3.92
        49.80:  0.64    48.14:  0.63    52.52:  0.64    NEDEF.:....     49.65:  0.64    49.65:
        0.64
        49.65:  0.64    49.65:  0.64
        47.84:  0.57    47.84:  0.57
        52.50:  0.64    NEDEF.:....
        NEDEF.:....     NEDEF.:....     PROPOSICE CISLO:  29  0
0
        PROPOSICE CISLO:  30  Ce4   8:      25.00   30.00   35.00   40.00 |  0.364   12 0.36 14
Ce2   8:      5.00    10.00   15.00   20.00 |  0.364   45 0.36 14
        0       1.96
        22.64:  0.00    NEDEF.:....     NEDEF.:....     NEDEF.:....     22.50:  0.00    22.50:
        0.00
        22.50:  0.00    22.50:  0.00
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....
        NEDEF.:....     NEDEF.:....     PROPOSICE CISLO:  31  Ce1   8:      0.00    2.00
8.00    10.00 |  0.400   48 0.40 14
        0       0.98
```

5.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 5.00: 0.40 5.00: 0.40
5.00: 0.40 5.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 32 Ce2 8: 5.00 10.00 15.00 20.00 | 0.364 45 0.36 13 0 0.98
12.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 12.50: 0.36 12.50: 0.36
12.50: 0.36 12.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 33 0 0
PROPOSICE CISLO: 34 0 0
PROPOSICE CISLO: 35 Ce5 8: 35.00 40.00 45.00 50.00 | 0.400 43 0.40 13 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 38 0.40 13 Ce2 8: 5.00 10.00 15.00 20.00 | 0.800 24 0.64 10 45 0.80 8
0 3.92
45.47: 0.40 12.55: 0.80 12.57: 0.80 NEDEF.:.... 38.82: 0.40 38.82: 0.40
38.82: 0.40 38.82: 0.40
12.50: 0.80 12.50: 0.80
12.50: 0.80 12.50: 0.80
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 36 0 0
PROPOSICE CISLO: 37 Ce9 8: 70.00 80.00 100.00 150.00 | 0.364 20 0.36 11 Ce7 8: 55.00 60.00 65.00 70.00 | 0.364 42 0.36 8 Ce0 8: 0.00 20.00 80.00 100.00 | 0.571 26 0.36 12 40 0.57 13 41 0.36 13 67 0.36 13 78 0.36 12 97 0.36 8 Ce2 8: 5.00 10.00 15.00 20.00 | 0.364 45 0.36 13 Ce1 8: 0.00 2.00 8.00 10.00 | 0.364 47 0.36 15
0 9.80
63.22: 0.57 49.84: 0.57 NEDEF.:.... NEDEF.:.... 54.47: 0.57 54.47: 0.57
54.47: 0.57 54.47: 0.57
50.00: 0.57 50.00: 0.57
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 38 Ce7 8: 55.00 60.00 65.00 70.00 | 0.400 79 0.40 13 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 35 0.40 13
0 1.96
50.22: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 51.55: 0.40 51.55: 0.40
51.55: 0.40 51.55: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 39 Ce9 8: 70.00 80.00 100.00 150.00 | 0.533 84 0.53 8 Ce0 8: 0.00 20.00 80.00 100.00 | 0.533 65 0.40 12 67 0.53 8
0 2.94
70.70: 0.53 69.05: 0.53 NEDEF.:.... NEDEF.:.... 65.86: 0.53 65.86: 0.53
65.86: 0.53 65.86: 0.53

73.00: 0.53 73.00: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 40 Ce7 8: 55.00 60.00
65.00 70.00 | 0.400 25 0.40 15 Ce3 8: 15.00 20.00 25.00 30.00 | 0.571 11
0.57 13 37 0.57 13 Ce0 8: 0.00 20.00 80.00 100.00 | 0.640 14 0.64 8 97 0.36 8
0 4.90
49.69: 0.64 49.52: 0.64 50.00: 0.64 NEDEF.:.... 47.08: 0.64 47.08:
0.64
47.08: 0.64 47.08: 0.64
44.52: 0.64 44.52: 0.64
50.00: 0.64 NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 41 Ce3 8: 15.00 20.00
25.00 30.00 | 0.364 37 0.36 13 Ce5 8: 35.00 40.00 45.00 50.00 | 0.400 88
0.40 11 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 65 0.40 9
0 2.94
49.43: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 46.35: 0.40 46.35:
0.40
46.35: 0.40 46.35: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 42 Ce3 8: 15.00 20.00
25.00 30.00 | 0.364 37 0.36 8
0 0.98
22.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 22.50: 0.36 22.50:
0.36
22.50: 0.36 22.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 43 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 35 0.40 13
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00:
0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 44 Ce0 8: 0.00 20.00 80.00 100.00 | 0.533 28 0.53 13
0 0.98
50.00: 0.53 50.00: 0.53 NEDEF.:.... NEDEF.:.... 50.00: 0.53 50.00:
0.53
50.00: 0.53 50.00: 0.53
50.00: 0.53 50.00: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 45 Ce9 8: 70.00 80.00 100.00 150.00 | 0.640 30 0.36 14
32 0.36 13 84 0.64 11 Ce3 8: 15.00 20.00 25.00 30.00 | 0.364 37 0.36 13 Ce0 8:
0.00 20.00 80.00 100.00 | 0.800 35 0.80 8 54 0.36 8 Ce1 8: 0.00 2.00
8.00 10.00 | 0.533 48 0.53 16
0 6.86
64.46: 0.80 62.73: 0.80 64.03: 0.80 NEDEF.:.... 73.08: 0.80 73.08:
0.80
73.08: 0.80 73.08: 0.80
67.11: 0.80 67.11: 0.80
69.90: 0.80 50.00: 0.80
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 46 0

0
PROPOSICE CISLO: 47 Ce3 8: 15.00 20.00 25.00 30.00 | 0.364 37 0.36 15
Ce0 8: 0.00 20.00 80.00 100.00 | 0.364 55 0.36 10 Ce1 8: 0.00 2.00
8.00 10.00 | 0.364 48 0.36 15
0 2.94
46.79: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 43.23: 0.36 43.23:
0.36
43.23: 0.36 43.23: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 48 Ce8 8: 65.00 70.00
75.00 80.00 | 0.364 60 0.36 8 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 31
0.40 14 Ce2 8: 5.00 10.00 15.00 20.00 | 0.533 45 0.53 16 Ce1 8: 0.00
2.00 8.00 10.00 | 0.364 47 0.36 15
0 3.92
45.88: 0.40 12.56: 0.53 NEDEF.:.... NEDEF.:.... 44.36: 0.40 44.36:
0.40
44.36: 0.40 44.36: 0.40
12.50: 0.53 12.50: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 49 0
0
PROPOSICE CISLO: 50 Ce9 8: 70.00 80.00 100.00 150.00 | 0.533 84 0.53 8
Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 68 0.40 13
0 1.96
74.83: 0.48 101.26: 0.53 NEDEF.:.... NEDEF.:.... 76.52: 0.53 76.52:
0.53
76.52: 0.53 76.52: 0.53
105.11: 0.53 105.11: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 51 0
0
PROPOSICE CISLO: 52 0
0
PROPOSICE CISLO: 53 0
0
PROPOSICE CISLO: 54 Ce2 8: 5.00 10.00 15.00 20.00 | 0.364 45 0.36 8
0 0.98
12.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 12.50: 0.36 12.50:
0.36
12.50: 0.36 12.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 55 Ce4 8: 25.00 30.00 35.00 40.00 | 0.400 62 0.40 11
Ce1 8: 0.00 2.00 8.00 10.00 | 0.364 47 0.36 10
0 1.96
21.57: 0.00 NEDEF.:.... NEDEF.:.... NEDEF.:.... 21.68: 0.00 21.68:
0.00
21.68: 0.00 21.68: 0.00
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 56 0
0
PROPOSICE CISLO: 57 Ce7 8: 55.00 60.00 65.00 70.00 | 0.400 25 0.40 9
0 0.98

62.50: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 62.50: 0.40 62.50: 0.40
62.50: 0.40 62.50: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 58 0
0
PROPOSICE CISLO: 59 Ce9 8: 70.00 80.00 100.00 150.00 | 0.533 96 0.53 14
Ce7 8: 55.00 60.00 65.00 70.00 | 0.400 25 0.40 9 Ce4 8: 25.00 30.00
35.00 40.00 | 0.400 12 0.40 8
0 2.94
89.19: 0.53 101.02: 0.53 NEDEF.:.... NEDEF.:.... 91.66: 0.53 91.66:
0.53
91.66: 0.53 91.66: 0.53
105.11: 0.53 105.11: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 60 Ce1 8: 0.00 2.00
8.00 10.00 | 0.364 48 0.36 8
0 0.98
5.00: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 5.00: 0.36 5.00:
0.36
5.00: 0.36 5.00: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 61 0
0
PROPOSICE CISLO: 62 Ce7 8: 55.00 60.00 65.00 70.00 | 0.364 25 0.36 10
Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 55 0.40 11
0 1.96
50.20: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 51.44: 0.40 51.44:
0.40
51.44: 0.40 51.44: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 63 Ce9 8: 70.00 80.00
100.00 150.00 | 0.400 84 0.40 8
0 0.98
104.76: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 106.24: 0.40 106.24:
0.40
106.24: 0.40 106.24: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 64 Ce9 8: 70.00 80.00 100.00 150.00 | 0.364 84 0.36 16
0 0.98
105.00: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 106.56: 0.36 106.56:
0.36
106.56: 0.36 106.56: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 65 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 41 0.40 9
90 0.36 10 Ce1 8: 0.00 2.00 8.00 10.00 | 0.400 39 0.40 12
0 2.94

47.08: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 47.77: 0.40 47.77: 0.40
47.77: 0.40 47.77: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 66 0
0
PROPOSICE CISLO: 67 Ce3 8: 15.00 20.00 25.00 30.00 | 0.400 37 0.36 13 99
0.40 8 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 28 0.40 8 Ce1 8: 0.00
2.00 8.00 10.00 | 0.533 39 0.53 8
0 3.92
45.40: 0.40 4.75: 0.53 NEDEF.:.... NEDEF.:.... 40.51: 0.40 40.51: 0.40
40.51: 0.40 40.51: 0.40
5.00: 0.53 5.00: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 68 Ce4 8: 25.00 30.00
35.00 40.00 | 0.400 12 0.40 13 Ce6 8: 45.00 50.00 55.00 60.00 | 0.400 50
0.40 13
0 1.96
42.50: 0.00 NEDEF.:.... NEDEF.:.... NEDEF.:.... 42.50: 0.00 42.50: 0.00
42.50: 0.00 42.50: 0.00
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 69 0
0
PROPOSICE CISLO: 70 0
0
PROPOSICE CISLO: 71 Ce9 8: 70.00 80.00 100.00 150.00 | 0.364 76 0.36 8
0 0.98
105.00: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 106.56: 0.36 106.56: 0.36
106.56: 0.36 106.56: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 72 0
0
PROPOSICE CISLO: 73 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 28 0.40 8
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00: 0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 74 0
0
PROPOSICE CISLO: 75 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 14 0.40 9
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00: 0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....

NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 76 Ce7 8: 55.00 60.00 65.00 70.00 | 0.364 71 0.36 8
Ce0 8: 0.00 20.00 80.00 100.00 | 0.364 91 0.36 8
0 1.96
50.22: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 51.56: 0.36 51.56:
0.36
51.56: 0.36 51.56: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 77 Ce0 8: 0.00 20.00
80.00 100.00 | 0.400 95 0.40 13
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00:
0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 78 Ce3 8: 15.00 20.00 25.00 30.00 | 0.364 37 0.36 12
0 0.98
22.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 22.50: 0.36 22.50:
0.36
22.50: 0.36 22.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 79 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 38 0.40 13
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00:
0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 80 0
0
PROPOSICE CISLO: 81 0
0
PROPOSICE CISLO: 82 Ce0 8: 0.00 20.00 80.00 100.00 | 0.364 27 0.36 13
0 0.98
50.00: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.36 50.00:
0.36
50.00: 0.36 50.00: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 83 Ce4 8: 25.00 30.00 35.00 40.00 | 0.364 12 0.36 15
0 0.98
32.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 32.50: 0.36 32.50:
0.36
32.50: 0.36 32.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 84 Ce9 8: 70.00 80.00 100.00 150.00 | 0.400 101 0.40 8
Ce7 8: 55.00 60.00 65.00 70.00 | 0.400 63 0.40 8 Ce4 8: 25.00 30.00

```
        35.00    40.00 | 0.400  12 0.40  8  Ce0     8:       0.00     20.00    80.00    100.00 | 0.364   64
0.36 16  Ce6     8:       45.00    50.00    55.00    60.00 | 0.533  50 0.53  8  Ce2     8:       5.00
        10.00    15.00    20.00 | 0.640  45 0.64 11  Ce1     8:       0.00     2.00     8.00     10.00      |
0.533  39 0.53  8
        0        6.86
        62.80:   0.40     24.81:   0.36     12.58:   0.64     NEDEF.:....      61.33:   0.40     61.33:
        0.40
        61.33:   0.40     61.33:   0.40
        24.53:   0.36     24.53:   0.36
        12.50:   0.64     NEDEF.:....
        NEDEF.:....       NEDEF.:....       PROPOSICE CISLO:  85  0
0
        PROPOSICE CISLO:  86  0
0
        PROPOSICE CISLO:  87  0
0
        PROPOSICE CISLO:  88  Ce9     8:       70.00    80.00    100.00   150.00 |  0.400  101 0.40  8
Ce0      8:       0.00     20.00    80.00    100.00 | 0.400  41 0.40 11
        0        1.96
        71.48:   0.40     NEDEF.:....       NEDEF.:....       NEDEF.:....      73.90:   0.40     73.90:
        0.40
        73.90:   0.40     73.90:   0.40
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....       PROPOSICE CISLO:  89  0
0
        PROPOSICE CISLO:  90  Ce0     8:       0.00     20.00    80.00    100.00 | 0.364  65 0.36 10
        0        0.98
        50.00:   0.36     NEDEF.:....       NEDEF.:....       NEDEF.:....      50.00:   0.36     50.00:
        0.36
        50.00:   0.36     50.00:   0.36
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....       0
        PROPOSICE CISLO:  91  Ce9     8:       70.00    80.00    100.00   150.00 |  0.364   76 0.36  8
Ce7      8:       55.00    60.00    65.00    70.00 | 0.364  25 0.36 16  Ce0     8:       0.00     20.00
        80.00    100.00 | 0.364  93 0.36 16
        0        2.94
        71.51:   0.36     NEDEF.:....       NEDEF.:....       NEDEF.:....      73.27:   0.36     73.27:
        0.36
        73.27:   0.36     73.27:   0.36
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....       PROPOSICE CISLO:  92  0
0
        PROPOSICE CISLO:  93  Ce0     8:       0.00     20.00    80.00    100.00 | 0.364  91 0.36 16
        0        0.98
        50.00:   0.36     NEDEF.:....       NEDEF.:....       NEDEF.:....      50.00:   0.36     50.00:
        0.36
        50.00:   0.36     50.00:   0.36
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....
        NEDEF.:....       NEDEF.:....       0
        PROPOSICE CISLO:  94  0
0
```

PROPOSICE CISLO: 95 Ce0 8: 0.00 20.00 80.00 100.00 | 0.571 14 0.57 8 77 0.40 13
0 1.96
50.00: 0.57 50.00: 0.57 NEDEF.:.... NEDEF.:.... 50.00: 0.57 50.00: 0.57
50.00: 0.57 50.00: 0.57
50.00: 0.57 50.00: 0.57
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 96 Ce7 8: 55.00 60.00 65.00 70.00 | 0.533 25 0.36 13 59 0.53 14
0 1.96
62.50: 0.53 62.50: 0.53 NEDEF.:.... NEDEF.:.... 62.50: 0.53 62.50: 0.53
62.50: 0.53 62.50: 0.53
62.50: 0.53 62.50: 0.53
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 97 Ce3 8: 15.00 20.00 25.00 30.00 | 0.364 37 0.36 8 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 14 0.40 10 40 0.36 8
0 2.94
49.55: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 48.25: 0.40 48.25: 0.40
48.25: 0.40 48.25: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... PROPOSICE CISLO: 98 Ce7 8: 55.00 60.00 65.00 70.00 | 0.364 25 0.36 10
0 0.98
62.50: 0.36 NEDEF.:.... NEDEF.:.... NEDEF.:.... 62.50: 0.36 62.50: 0.36
62.50: 0.36 62.50: 0.36
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 99 Ce0 8: 0.00 20.00 80.00 100.00 | 0.400 67 0.40 8
0 0.98
50.00: 0.40 NEDEF.:.... NEDEF.:.... NEDEF.:.... 50.00: 0.40 50.00: 0.40
50.00: 0.40 50.00: 0.40
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:....
NEDEF.:.... NEDEF.:.... 0
PROPOSICE CISLO: 100 0
0