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EVALUATION OF INVESTMENT PORTFOLIO BY APPLICATION OF MULTI-CRITERIA DECISION MAKING METHODS USING ROBO-ADVISOR

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A B S T R A C T

Paper describes the creation of algorithm for automated assessment of investment portfolio attractiveness. Portfolios selection procedure (algorithm) are considered. Comparison of multiple criteria evaluation methods and comparison of the prioritization ranking of different investment projects (portfolios) following changes to the requirement weights are introduced. Evolving of robo-advisor systems for portfolio management is described. Research goal is development of algorithm for automated assessment of investment attractiveness of portfolios using investment criteria. Ex-ante (predict) and ex-post (assess) evaluation are compered for project evaluation. Research methods include algorithms for assessing the investment attractiveness of portfolios using finance criteria. To integrate these criteria scoring system for selection of investment portfolios was implemented with transformation model from quantitative criteria to qualitative ones. Scoring method was applied for different investment portfolios with cryptocurrencies to choose most attractive for investors.

1. INTRODUCTION

Due to the rapid development of the innovative economy and the commercialization of software products, there is a need for software that provides automated analysis of financial indicators of various projects and help investors make decisions on choosing the most investment-attractive projects according to certain equivalent criteria (Kilinich et al., 2019).

The variety of opportunities for investors and the availability of projects with different financial key performance indicators according to different criteria makes it necessary to automate the calculation of these indicators to speed up the preliminary analysis of business ideas and start-ups to filter out projects with a high level of risk according to certain evaluation criteria (Snihovyi et al., 2019). It gives opportunity for a more in-depth analysis of the most investment-attractive projects based on additional criteria (Keeney et al., 1993).

The implementation of investment goals requires the formation of investment projects that provide the investor and other stakeholders with the necessary key performance indicators for making investment decisions (Levišauskait, 2010). Investments give enterprises more opportunities for development and growth, and they are necessary due to scarce resources for the enterprise.

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However, investors are primarily interested in returning the initially invested funds, their capitalization and making a profit, i.e. payback period is very important (Kuo et al., 2015).

To assess the investment attractiveness of projects and determine the effectiveness of expected investments, as a rule, the experts are involved, who have professional competences in the relevant areas of economic and financial analysis, management accounting, marketing research, portfolio investments, tax planning, etc.) (Kobets et al., 2016). Consulting firms hire such personnel that provide relevant services to enterprises. At the same time, the cost of this service is not available to many firms under economic crisis and recession. Thus the best opportunity to analyse the investment project of the enterprise using its financial and economic indicators to reveal project investment attractiveness is training of own specialist in modern IT methods of investment design and the use of special software, which helps to solve the technical tasks (Kobets et al., 2018).

A correctly designed investment project should answer the main question: should firm invests in this project and will firm make a profit from it in the future? An important issue is to design an investment project in accordance with generally accepted requirements and make the necessary calculations. It helps firm to identify KPI of projects in advance and assess whether they can be overcome, as well as understand where you need to insure in order to reduce expected risks (Hyll et al., 2015).
As the gap between the available funds and investment needs widens, identifying the most sustainable projects becomes a critical activity. The purpose of the paper is to describe creation of software for automated assessment of investment attractiveness of projects.

The remaining part of the paper is structured as follows: section 2 considers literature review; section 3 describes methodology (models of decision making for robo-advisors); section 4 presents the findings concerning applied scoring method to select most attractive investment portfolio; last section concludes.

2. LITERATURE REVIEW

2.1 Project selection procedure

Need of society to invest in each public project is defined through the consideration of its contribution to the regional balance, the scope of its investment. These investments can have economic, environmental, and social impacts. The selection of all the proposed projects is quite obviously impossible.

Decision-makers need to consider how to maximize their return on the investment of private or public funds. Human decision-makers have difficulties handling large amounts of complex information in a consistent way to assure rational and systematic choices based on economic, social and environmental grounds. A score ranging from minimal value (very poor) to maximal value (very high) depending on the level of improvement provided by the investment projects is assigned to each issue.

There are different institutional types of investors, such as private individuals, corporations or investment funds, which use current resources to gain the maximum benefits from the investments and consider alternative projects selection, investment resources allocation (Ginevičius et al., 2009). They make capital investment in heterogeneous public or private projects in different industries: construction, IT, green energy, water. A large number of non-homogeneous investment projects are proposed every year to the investors (government, local authority or firms) by many different stakeholder agencies taking into account needs of society. Development of projects substantially depends on stakeholders who include customers, suppliers, government, developers, renters and investors.

Project selection procedure (algorithm) includes following steps:
1. Identification of investor’s main goal and targets.
2. Projects’ selection (initial projects’ data gathering about alternatives), unprofitable projects are eliminated for private investors.
3. Establish of criteria set and attractive projects’ parameters (to create questionnaires to get grades from experts about criteria which impact to project, expert interview about demand for the product of projects, taxes, risk analysis, expected price of raw materials).
4. Analysis and comparison of the parameters (to construct hierarchical structure of the criteria).
5. Evaluate alternatives using multiple criteria evaluation of projects’ efficiency (structure of (sub)criteria and weights are defined and assigned, quantitative and qualitative evaluations to prioritize the project).
6. Conclusions and recommendations about projects’ efficiency (to evaluate alternatives and prepare a rank of the projects, counting of total scoring using, e.g., software tools).
7. Investment decision-making (to choose the best alternative from existing ones).

Earned Value Management (EVM) measures project performance against a baseline plan and identifies deviations in budget and schedule (Tariq et al., 2020). The multivariate regression model can be used to evaluate the influence of individual element on the overall estimated cost of the project. EVM methodology considers scope, time and cost indices while measuring the performance and progress of the project (Tariq et al., 2020). This technique uses different indices, cost variance and schedule variance, forecasting mechanisms. Authors (Tariq et al., 2020) selected most contributing elements to project: 1) project mission, 2) stakeholder expectations, 3) capable team member, 4) project schedule, 5) initial cost estimates, 6) technology, 7) key deliverables, 8) business plan. Project performance can be enhanced by assigning weight to the extracted effects.

Project prioritization of a non-homogeneous set of alternative investments is a widely used tool to evaluate and to rank projects (Fig. 1).

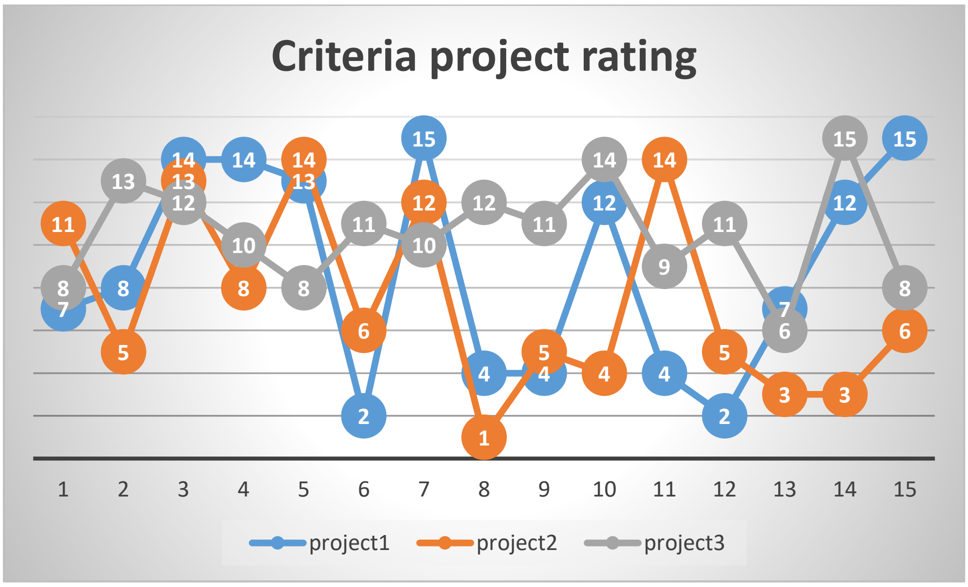

Figure 1. Comparison of the prioritization ranking of different projects following changes to the requirement weights

2.2 Criteria, indicators and scores of projects

Investment project decisions involve a diverse set of quantitative and qualitative criteria, such as hybrid multi-criteria decision method to facilitate conversion between criteria domains (Brelih et al., 2019). When decision process carry out ad hoc without systematic methodological support then best alternative can be missed.

Higher level (aggregated) criteria are composed of two or more lower-level criteria. The values of criteria are measured (elementary criteria) and calculated (aggregated criteria) in a bottom-up manner. The value of this criterion represents the general score of the decision variant, and it is used to compare the variant with other variants (Brelih et al., 2019). Each criterion has its intrinsic domain for quantitative criteria from least till most desirable values. Qualitative criteria are ordered from the least desired value till the most desired value. Expert judgement criteria consist of (a) performance; (b) technical experience; (c) stability of finances; (d) management performance/employee qualification; (e) capacity; (f) record of safety; (g) equipment operation.
Microeconomic and macroeconomic environment determines the risk levels and complexity of projects realization. 'The selection of appropriate model and methods can solve the problem of risk and uncertainty management in investment decision-making' (Ginevičius et al., 2009). To choose stability project and identify process improvements it is necessary to learn how to identify, analyze, mitigate and manage the risks in real projects (Mon et al., 2020).

All criteria have some indicators to measure their progress. Sustainability dimensions (ecological, financial, and social) have impact on the prioritization processes. The levels range from the most general to the most specific: requirements, criteria, and indicators. Each evaluation can be done using qualitative or quantitative variables. The 'value function is a single mathematical function that converts the qualitative and quantitative variables of the indicators, with their different units and scales, into a single scale from 0 to 1' (Pujadas et al., 2017). For different criteria, heterogeneous projects can have different ranks on different positions (Fig. 1). Due to this reason, set of criteria has to be replaced on value function, which consists of single number. 'The method can be adapted, if the decision-makers change the criteria by modifying the weights and the value functions that are assigned to them' (Pujadas et al., 2017). However, hardly to determine the criteria weights based on the expert evaluation, when there are the relationships between the criteria of the projects (Ginevičius et al., 2009). We can assess the weights of subordinated criteria based on the set of if-then rules using regression and the linear least squares method (Brelih et al., 2019).

An effective solution would be to reduce the number of criteria, e.g., eliminating some criteria and retaining only key indicators in a set. At the same time, the more criteria are eliminated, the less accurate is the description of the project. The other method is associated with grouping the criteria as hierarchically structured system for further treatment (e.g., economic efficiency and projects' criteria) (Ginevičius et al., 2009).

Realization of investment projects imposes the need for estimating its efficiency. Analysis of particular relevant elements, technological, market, financial, staff, ecological, social and other variables reveal projects advantage, which can be based on financial profitability, total impact of project on environmental, because the effectiveness of investments can be considered from many aspects – economic, social, political, strategic etc. (Vasovic et al., 2012). Each of the compared alternatives is valued in the system of various, often diverse criteria given in various units and we need approach how to use a few projects' criteria as possible in order to express all the complexity and versatility of the considered projects (Vasovic et al., 2012).

Project managers consider ways to choose projects using comprehensive set of criteria, which led to the creation of a decision-making model through analytic hierarchy process (AHP) method and the Expert Choice computer program (Erdogan et al., 2019). Fig. 2 shows a pyramid (hierarchy) of different available approaches, which are applied to select the proper projects and develop model for decision-making where multiple criteria (as a rule in contradiction) are exist (Erdogan et al., 2019).

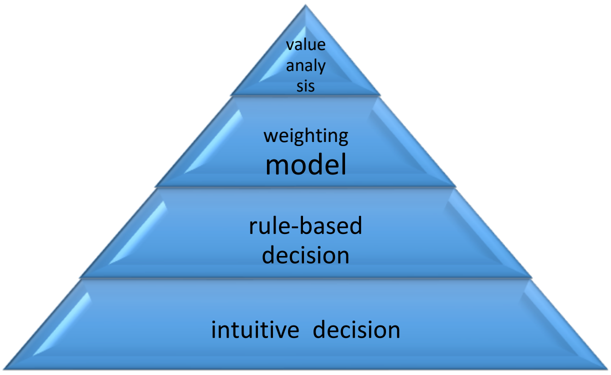

Figure 2. A pyramid of decision hierarchy

Some of criteria can be subjective; others measured numerically (Table 1).

Table 1. Comparison of multiple criteria evaluation methods

Method	Requirements to criteria	Calculation procedure	Complexity	Examples
Delphi method	Numeric values	Weights according to max and min values	Very simple	Lecturer recruitment
Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)	Qualitative and quantitative values	Vectoral	Simple	Choice of operating system, selection of sustainable investment, supplier selection
Multi-Criteria Decision Analysis (MCDM)	Qualitative and quantitative values	Scoring	Simple	Construction projects, public projects
Analytic Hierarchy Process (AHP)	Qualitative and quantitative values	Matrix	Medium	Selection of suitable bridge construction method, IT projects, selection of software projects
COmplex PRoportional ASsessment (COPRAS)	Qualitative and quantitative values	Optimization methods	Complex	Material selection and new product development, construction project selection
Multi-Criteria Decision Analysis (MCDM)	Qualitative and quantitative values	Scoring	Simple	Construction projects, public projects

Quantitative criterion (xquant) can be transformed into qualitative criterion (xqual) to make decision using transformation function t (Brelih et al., 2019) (Fig. 3):

$$x_i^{qual} = t(x_1^{quant}; x_2^{quant}; \dots; x_n^{quant}) \quad (1)$$

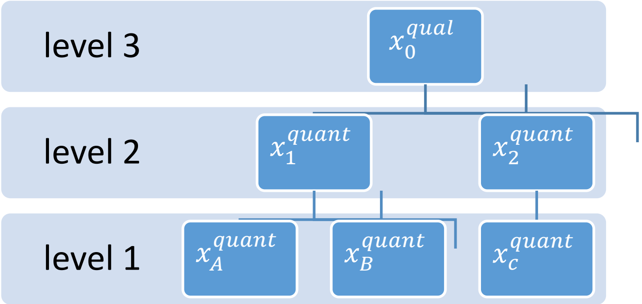

Figure 3. Transformation model from quantitative criteria to qualitative one

All values of xquant are mapped into a single qualitative value (Fig. 4).

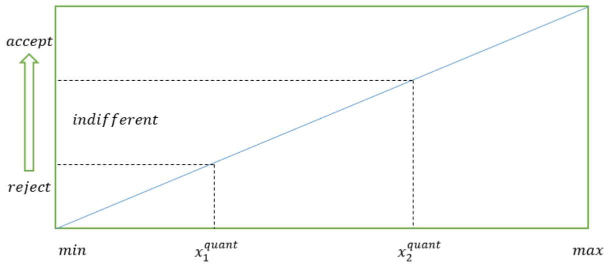

Figure 4. Graphical presentation of a transformation function t that transforms quantitative values into qualitative decision

The measurement of a projects' success or failure has to be measured against well-defined objectives and criteria to allow an objective assessment of progress (Fig. 5) (Irani, 2010).

Scale	Unacceptable [0-20)	Acceptable [20-37)	Good [37-64)	Very Good [64-80)	Excellent [80-100]	Projects (portfolios)
Criterion 1						1
						2
						…
						N
Criterion 2						1
						2
						…
						N
…						1
						…
						n
Criterion m						1
						2
						…
						n

Figure 5. Graphical representation of projects ranked by the selected criteria (Harrington scale)

2.3 Methods and models of investment projects evaluation

There are various methods of investment projects evaluation. Among them are financial, risk assessment, multiple criteria evaluation and other methods. Each of these methods has particular advantages and disadvantages. Method can be presented as algorithm, 'which able to determine efficiency of investment projects in accordance to investor's needs and to set projects' priorities list' (Ginevičius et al., 2009). Method has to perform accurate, consistent, and repeatable evaluations. Quantitative method aims to calculate a unique number (value) that represents the overall strength of each alternative, considering all criteria (Brelih et al., 2019). Multi-attribute utility function (MAUF) describes the preferences of a decision maker (axioms of rational person in microeconomics).

The methods main strength is the possibility to utilize qualitative and quantitative criteria in the same model and perform both qualitative and quantitative evaluation, which reduces the time required to select a project (Brelih et al., 2019). Using game-theory, instead of prioritizing individual projects one by one, the most sustainable group or combination of projects can be prioritized if interests of stakeholders are opposite (Pujadas et al., 2017).

Decisions are taken according to clear, consistent and transparent criteria assisted by the multi-criteria analysis framework. This methodology combines multi-criteria decision making (MCDM) and multi-attribute utility theory (MAUT), incorporating the value function (VF) concept and assigning weights through the analytic hierarchy process (AHP). Weights of the criteria reflect criteria significance on project's efficiency. 'VF is proposed for each indicator, in order to convert each evaluation to a number from 0 to 1, thereby defining equivalences between the different units of the indicators' (Pujadas et al., 2017).

Monetary-based decision-support techniques are cost-effectiveness analysis, where the costs of different homogeneous alternatives are compared, financial analysis; and cost-benefit analysis. In these circumstances multi-criteria analysis (MCA) techniques maybe useful. Main contribution is that it combines multi-criteria decision making (MCDM) and multi-attribute utility theory (MAUT) assigning weights using the analytic hierarchy process (AHP). This methodology provides rational sustainability based reasoning for the decision criteria (Pujadas et al., 2017). Multi-criteria methodology has been developed to assist decision-makers in finding strategies for the prioritization and selection of heterogeneous investments projects for the assessment of sustainability (Table 1).

Expert method is used to evaluate a project. For example, criteria weights can be determined by scale scores from min to max values. To determine the degree of agreement between the expert estimates, the Kendall concordance coefficient is used (Ginevičius et al., 2009). Delphi method is utilized to identify the critical success factors (CSFs). Optimization methods include multi-criteria, cost-oriented, single-objective, multi-objective.

MCDM is aimed at supporting decision makers who are faced with making numerous and conflicting evaluations (Pangsri, 2015). Multi-criteria framework is used to evaluate the degree to which each investment would contribute to sustainable development.

Analytic Hierarchy Process is designed to determine the weights of the decision criteria using Saaty (Saaty, 2005) rating scale (equal importance, somewhat more important, much more important, very much more important, and absolutely more important) (Pangsri, 2015). Analytic hierarchy process (AHP) reflects the relative importance of each requirement, criterion and indicator for the purposes of the prioritization. 'AHP is a linear additive model (A2) that converts subjective assessments of relative importance into a set of overall scores or weights based on pairwise comparisons between criteria and between options. In assessing weights, the decision-maker is asked a series of questions to take into account how important one particular criterion is' (Pujadas et al., 2017).

$$x_i^{quant} = \sum_{k=1}^{n} w_k \cdot x_k^{quant} \quad (2)$$

where x_i^{quant} has n (two or more) subordinate criteria and w_k represents the weight of criterion x_k^{quant}.

TOPSIS is used to rank the alternatives and means that optimal solution should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution (Pangsri, 2015).

Different MCDMs can yield different rankings of decision variants and the task of the decision-making model is to help the investor identify and rank investment projects (Brelih et al., 2019).

The majority of hybrid MCDM is applied in such areas as computer science, engineering, operational research and management science, business economics, mathematics, energy fuels, and environmental sciences ecology (Brelih et al., 2019). HMCDM integrated the quantitative (MAUT) and qualitative (DEX) methods in the decision-making model, and implemented it in real-world projects.

Project manager can prioritize project by combining three methods including Expert interviews, the Analytic Hierarchy Process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) in group decision-making (Fig. 6). Other examples of methods integration are MAUT and DEX, DELPHI and expert scoring method.

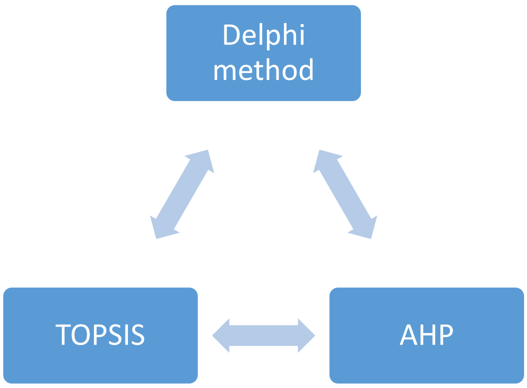

Figure 6. Example of hybrid MCDM in research framework (combining of 2 and more methods)

Investment project decisions involve a diverse set of quantitative and qualitative criteria using MCDM that is based on the multi-attribute utility theory (MAUT) and decision expert (DEX) methods. DEX method can aggregate qualitative criteria into a higher-level qualitative criterion. Hybrid criteria convert a quantitative criterion into a qualitative criterion. DEX is a rule-based method, e.g., if-then decision rules. This method supports two types of utility functions, i.e., weighted sum for quantitative criteria and if-then rules for qualitative criteria, and implements a novel algorithmic criteria type conversion function to support both types of criteria (Brelih et al., 2019).

Consider example of this hybrid approach. If the scores of two different projects are the same (Scor1 = Scor2), a qualitative analysis should be used to determine which of the indicators is more important than the others. If PI2> PI1 and Scor1 = Scor2, then U(Project2)>U (Project1), where U means investor's utility, PI is a profitability index.

Expert scoring method is the most popular method for Decision Analysis and Resolution (DAR) for software projects, and Delphi principle was proposed to improve the expert scoring method (Fig. 7) (Hou et al., 2017).

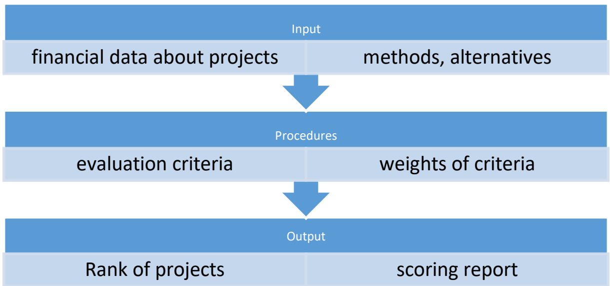

Figure 7. Decision making analysis and resolution

Fig. 7 demonstrates inputs: benefit, cost, time, discount rate and outputs: economic benefits, input output ratio as effectiveness index. Thus, the model of projects selection (Ginevičius et al., 2009) 'is designed for alternative projects, variants selection, investment resources allocation, value maintenance. The model efficiency evaluation covers all the investment decision-making cycle, hierarchically structured projects' evaluation criteria system, risk evaluation basing on stochastic dimensions as well as the mathematical methods adaptation for multiple criteria evaluation problems solution, risk assessment and adjusted mathematical methods'. The decision-making model is used to evaluate the variants, i.e., potential investment projects according to their characteristics (Brelih et al., 2019).

2.4 Information technology and information systems for decision making

Digital technology allows flexible and efficient planning, management, and implementation of projects (Erdogan et al., 2019). IS use the input from the operator's team of experts to calculate necessary indices (benefits, costs and discount rate). A user-friendly software implementation can hide the complexity from the end-users (Brelih et al., 2019). The task of the developed software is to facilitate decision-making, reducing the time required to reach a decision, improving decision quality and consistency, and increasing transparency in the investor's choice of investment projects (Brelih et al., 2019). The decision-making model is implemented as a software containing the formal representation of the investor's decision criteria. Software is expected to be applicable to similar decision problems for initial data of different projects.

It is important to estimate a contribution through exploring project management from the perspective of information systems (IS) investment evaluation (Irani, 2010). It will increase the motivation of project managers to appropriately evaluate the impact of their IS before, during and after the investments in the projects which increase the prospects of project success (Irani, 2010). IT-based projects can be classified as follows: strategic, turnaround, factory or support (Fig. 8) (Irani, 2010).

There are lack of understanding as to why, how and when to explore IS for decision making about accept/reject projects, thus to improve management of IS projects there is need to embed investment evaluation within the project management process which can help an organization better utilize resources (Irani, 2010). Traditionally, the evaluation of projects adopt standard indexes such as NPV, IRR, etc, but this approach do not consider other important non-financial criteria (Irani, 2010). Expectations of investors about projects have to include positive, negative and the most probable scenario under consideration in IS.

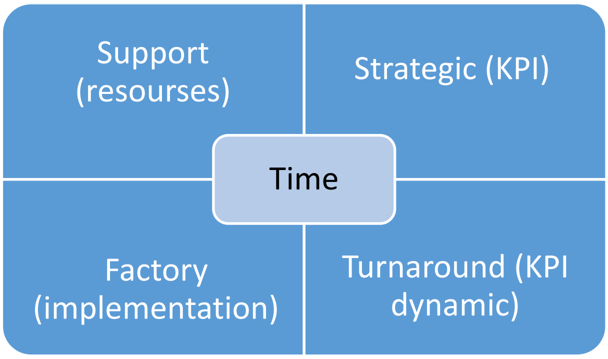

Figure 8. Evolving deployment of information systems

Authors (Yao et al., 2019) for AHP, Delphi and CMM grading methods, the index weight is calculated by software to estimate the comprehensive evaluation score and the evaluation interval. Indicators of economic and social benefits arising from information management of projects.

Information technology and systems make investment process change from traditional management mode to information management mode to build a complete evaluation system of informatization management maturity of projects, which vary across initial stage, technical support level, management mode level, integrated integration level till the optimizing level (Yao et al., 2019). All these levels are calculated using detailed scoring rules as product of weights and corresponding indexes.

2.5 Project evaluation

External measures are include market share, share value and customer satisfaction and require clear strategies for achievement through the eyes of its stakeholders (key performance indicators). Internal measures include project efficiency, with project cost, time and quality and based around plans of investor to discussing, grading, and selects the optimal plan (Fig. 9).

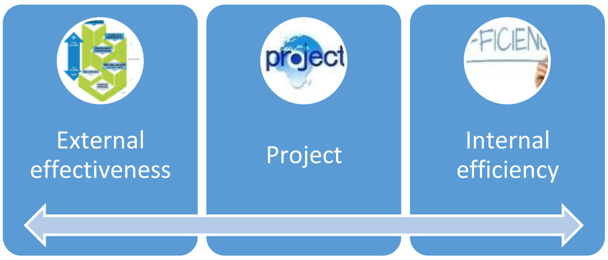

Figure 9. Strategy and implementation stage of project

Ex-ante evaluation, metrics (monitor progress of KPI), command and control (assess of project plan using benchmarking) and ex-post evaluation are types of IS assessing for project evaluation (Irani, 2010).

Ex-ante (predict) evaluation have significant implications on the management of the project from the perspective of attitude to risk, cash-flow of the organization, timing of benefits and outflow of costs. Strategic vision corresponds transition from top-right quadrant (investment) through to traditional techniques for the top-left quadrant (consumption) (Fig. 8).

Ex-post (assess) evaluation is a post implementation review stage to reflect on the level of success to correct past mistakes (Irani, 2010). To review performance against set measures (cost, benefit and risk review with an alignment of expected against realized results).

There is strong link between ex-ante and ex-post evaluation through robust project management. The purpose of evaluation as a management activity is to predict (ex-ante) or assess (ex-post) how well IS project meets the expectations of stakeholders (Irani, 2010). Investment evaluation needs to be viewed as a parallel management activity to project management, where investment decisions are closely mapped to the costs, benefits and risks to underpin the decision of whether to invest or not.

Researches plan to bridge the gap between organizational strategy and project delivery, with the evaluation process (ex-ante and ex-post) to develop algorithms to support the decision-making about project accept or reject from the perspective of information systems investment evaluation. (Irani, 2010).

Strategic and turnaround quadrant create opportunities for an investment, whereas support or factory quadrant can be considered as implementation phase. Ex-ante evaluation is a process from the following steps: strategic (top right): key performance indicator about investment process; support (top left): cost-benefit analysis (resource consumption); operational to tactical (bottom left): scenario planning; tactical to strategic (bottom right): multi-criteria to evaluate the projects (Fig. 8).

The increasing diversity of IS applications has led to a range of different project types from strategic vision to the daily use of IS for an operational role (Irani, 2010). Development of IS for projects can move through following options. No choice option – mandatory investment in a projects using IS (defense equipment etc.): bottom-left quadrant. Infrastructure investments are intended to enable some future systems or services of IS to make grounded investment decision: the top-left quadrant. Research investments - learning about the next generation of technologies or IS. They are usually long-run and difficult to quantify financially: top-right quadrant.

3. METHODOLOGY: MODELS OF DECISION MAKING FOR ROBO-ADVISORS

3.1 Methods and models of investment projects evaluation

Each goal of the investor may correspond to his/her different attitude toward the risk:

- conservative with risk minimization (risk averse attitude for savings on education, retirement fund);
- aggressive with maximizing profitability (risk seeking to start a new startup).
- moderately aggressive with the desire to achieve simultaneously minimal risk at maximum profitability (risk neutral attitude for optional goals, such as savings for a new house).

The first restriction imposed on the investment portfolio is the positive shares of all financial instruments: $x_i > 0$. The second restriction is that the sum of all shares of securities has to be 1, this is the rule of share rationing: $\sum_{i=1}^{n} x_i = 1$.

The return on the portfolio will look like a sum of the returns of individual financial instruments with selected weights. As the aggressive investor tries to maximize the return on the portfolio, it will be necessary to maximize the relevant objective function. As a result, it will look like the following formula: $\sum_{i=1}^{n} m_i x_i \to max$.

In addition to affordable profitability, the investor has to consider the risk associated with the investment portfolio of financial instruments. The risk according to the Markowitz model is expressed as the standard deviation σ_i of each financial instrument. The value of σ_p is the level of acceptable risk for the investor. In addition to the standard deviation of financial instruments, it is necessary to review the correlation between the profitability of different fininacial instruments r_{ij}. As a result, the risk of the entire portfolio is represented by formula (3):

$$\sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sigma_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} x_i x_j r_{ij}\sigma_i\sigma_j} < \sigma_p \qquad (3)$$

Mathematical model of optimal portfolio of financial instruments for the aggressive type of investor with maximum efficiency, where the portfolio risk does not exceed the specified value σ_p, considering all restrictions on the portfolio, will be as follows (4):

$$\begin{cases} \sum_{i=1}^{n} m_i x_i \to max\,; \\ \sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sigma_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} x_i x_j r_{ij}\sigma_i\sigma_j} < \sigma_p; \\ \sum_{i=1}^{n} x_i = 1\,; \\ x_i > 0,\ \ i = 1, \dots, n. \end{cases} \qquad (4)$$

The inverse task of portfolio optimization is to choose a portfolio structure, which profitability is higher or equal to the expected investor value of m_p with minimal risk. This results in a portfolio for the conservative type of investor. The mathematical model of the problem in this case has the following form:

$$\begin{cases} \sum_{i=1}^{n} m_i x_i \geq m_p\,; \\ \sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sigma_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} x_i x_j r_{ij}\sigma_i\sigma_j} \to min; \\ \sum_{i=1}^{n} x_i = 1\,; \\ x_i > 0,\ \ i = 1, \dots, n. \end{cases} \qquad (5)$$

When developing a portfolio for a neutral type of investor, both risk minimization and profit maximization occur. Thus, we obtain the following mathematical model of the problem (6):

$$\begin{cases} \dfrac{\sqrt{\sum_{i=1}^{n} x_i^2 \cdot \sigma_i^2 + 2\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} x_i x_j r_{ij}\sigma_i\sigma_j}}{\sum_{i=1}^{n} m_i x_i} \to min; \\ \sum_{i=1}^{n} x_i = 1\,; \\ x_i > 0,\ \ i = 1, \dots, n. \end{cases} \qquad (6)$$

3.2 Portfolio scoring procedure

The development of a scoring indicator will meet the requirements of integral assessment and usability of the portfolio investment methodology.

We propose to use scoring model, which includes combination of financial criteria, to selecting projects. The scoring method is based on the procedure shown in Fig. 10.

For the described procedure of portfolio selection, we propose the following evaluation system (Table 2).

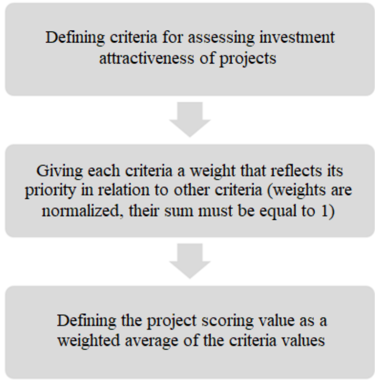

Figure 10. Portfolio scoring procedure

Table 2. Scoring system for selection of investment portfolio

№	Criteria	Weight	Value
1	Return (m_p)	0.25	1 – negative; 2 – negative, but can become positive if option apply; 3 – positive; 4 – positive, can be increased if option implement
2	Risk level (σ_p)	0.25	4 – [0; Min (risk neutral; risk averse)] 3 – (Min (risk neutral; risk averse); Max (risk neutral; risk averse)] 2 – (Max (risk neutral; risk averse); Risk seeking] 1 – (Risk seeking; ∞)
3	Risk / return ratio	0.25	4 – (0; 1/3) of negative deviation of expected interest rate; 3 – (1/3; 2/3) of negative deviation of expected interest rate; 2 – (2/3; 1) of negative deviation of expected interest rate; 1 – (1; ∞) of negative deviation of expected interest rate 0 – if return rate is negative
4	Credit (interest) rate	0.25	0 – there is no satisfactory interest rate 1 – less than the interest rate; 2 – slightly more than the interest rate; 3 – considerably more than the interest rate; 4 – significantly more than the interest rate taking into account pessimistic scenario

In this assessment system, we have identified 4 most important criteria for the investment portfolio. Calculated value of each criteria in accordance with Table 2 can score from 0 to 4 points. Depending on the weight of each criterion, the overall investment portfolio attractiveness is estimated by the formula:

$$Z_k = \sum_j w_j * S_{jk}, \qquad (7)$$

where w_j is weight of criteria j, S_{jk} - value of project S by criteria j, which vary from 0 to 4 points, where 4 points is the maximum value of the scoring indicator of portfolio investment attractiveness.

4. FINDINGS

We can consider times series of cryptocurrencies price of BTC-USD, ETH-USD, LTC-USD, NEO-USD, BCH-USD using open data from August, 6, 2017 till June, 23, 2018 from https://finance.yahoo.com/cryptocurrencies/. If we apply formulas (4)-(6) then we can obtain following results (Table 3).

Table 3. Types of investment portfolio

Investment portfolio	Averagr return per year	Average risk per year	Risk / Return
Risk averse	237%	2412%	10.2
Risk neutral	184%	2002%	10.9
Risk seeking	316%	3761%	11.9

Table 4 describes distribution of investment costs among financial instruments for different portfolios types.

Table 4. Distribution of investment costs among cryptocurrencies

Crypto currencies	Types of investment portfolio		
	Risk averse, %	Risk neutral, %	Risk seeking, %
BTC-USD	29	55	0
ETH-USD	0	9	0
LTC-USD	7	2	0
NEO-USD	25	12	0
BCH-USD	39	22	100

Investment portfolio of risk averse investor includes Bitcoin Cash (39% BCH-USD), Bitcoin (29% BTC-USD), NEO (25% NEO-USD) and Litecoin (7% LTC-USD) (Figure 11).

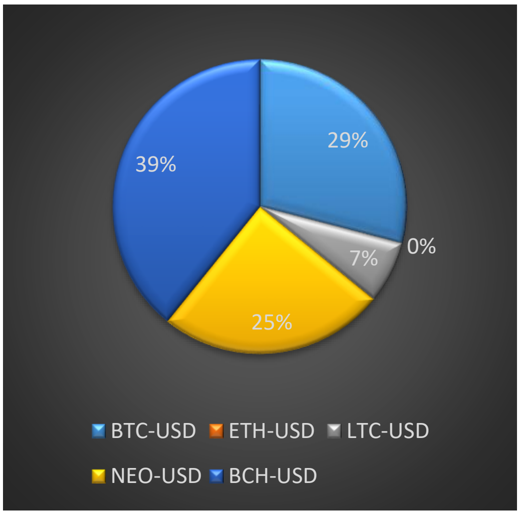

Figure 11. Risk averse investor portfolio

Investment portfolio of risk neutral investor includes Bitcoin (55% BTC-USD), Bitcoin Cash (22% BCH-USD), NEO (12% NEO-USD), Ethereum (9% ETH-USD) and Litecoin (2% LTC-USD) (Figure 12).

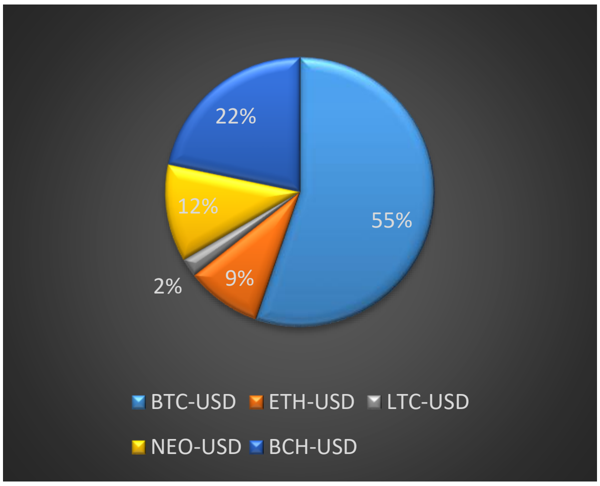

Figure 12. Risk neutral investor portfolio

Investment portfolio of risk seeking investor includes only Bitcoin Cash (100% BCH-USD).
Taking into account scoring system for selection of investment portfolio (Table 3), we can calculate overall investment portfolio attractiveness Z_k for 3 types of investment portfolios (Table 5). The results are presented in Table 6 (annual average credit rate is assumed at 30%, https://minfin.com.ua/company/privatbank/credits).

Table 5. Calculation of overall investment portfolio attractiveness.

Criteria	Types of investment portfolio		
	Risk averse, %	Risk neutral, %	Risk seeking, %
Return (m_p)	S1=3 (237% > 0)	S1=3 (184% > 0)	S1=3 (316% > 0)
Risk level (σ_p)	S2=1 (10,2 > 1)	S2=1 (10,9 > 1)	S2=1 (11,9 > 1)
Risk / return ratio	S3=4 [0; Min (risk neutral; risk averse)]	S3=3 (Min (risk neutral; risk averse); Max (risk neutral; risk averse)]	S3=2 (Max (risk neutral; risk averse); Risk seeking]
Credit (interest) rate	S4=3 (credit rate 30% < 237%)	S4=3 (credit rate 30% < 184%)	S4=3 (credit rate 30% < 316%)
Total score (Z_k)	$Z_1 = (3+1+4+3)/4 = 2.75$	$Z_2 = (3+1+3+3)/4 = 2.5$	$Z_3 = (3+1+2+3)/4 = 2.25$

The maximal scoring indicator 2.75 out of 4 points belongs to risk averse investor portfolio. It means that portfolio is most attractive to investor, profitable, most attractive risk/return ratio and is recommended for investments.

We can use any financial instruments (shares, bonds, commodities, gold, ETF, real estate) for investment portfolio to construct new investment proposals through scoring method taking into account risk preferences of investors and their goals.

5. CONCLUSION

Portfolio selection procedure (algorithm) is important approach, which give necessary information to compare different alternatives. Qualitative and quantitative criteria and indicators determine scores of investment portfolios. Transformation model from quantitative criteria to qualitative ones facilitate decision-making. Most important methods of investment projects evaluation are Delphi method, analytic hierarchy process and multi-attribute utility theory.

Implementation of portfolio selection algorithm helps to distinguish most attractive portfolio under determined criteria. Ex-ante (predict) evaluation and ex-post (assess) evaluation are used to compare predicted and actual results to make necessary adjustment in decision making about portfolios' acceptance/rejection.

Availability of portfolio with different financial key performance indicators according to different criteria makes it necessary to automate the calculation of these indicators to speed up the preliminary analysis of business ideas and start-ups to filter out projects with a high level of risk according to certain evaluation criteria. It gives opportunity for a more in-depth analysis of the most investment-attractive portfolios based on additional criteria.

Scoring method can to be applied for different financial instruments (shares, bonds, commodities, gold, ETF, real estate) taking into account risk preferences of investors and their goals. In future research, we plan to develop different investment portfolios, which depend on goal of investors, time horizon and their incomes.

References:

Brelih, M., Rajkovic, U., Ružic, R., Rodic, B., & Kozelj, D. (2019). Modelling decision knowledge for the evaluation of water management investment projects. *Central European Journal of Operations Research*, *27*(4), 759-781. doi: 10.1007/s10100-018-0600-5

Erdogan, S.A., Šaparauskas, J., & Turskis, Z. (2019). A Multi-Criteria Decision-Making Model to Choose the Best Option for Sustainable Construction Management. *Sustainability, 11*(8), 2239. doi: 10.3390/su11082239

Ginevičius, R., & Zubrecovas, V. (2009). Selection of the optimal real estate investment project basing on multiple criteria evaluation using stochastic dimensions. *Journal of Business Economics and Management*, *10*(3), 261-270. doi: 10.3846/1611-1699.2009.10.261-270

Hou, J.,& Meng, X. (2017). Application of Improved Expert Scoring Method with Delphi Principle in CMMI DAR Process Area. *Advances in Computer Science Research*, *71*, 30-33. doi: 10.2991/icmmita-16.2016.6

Hyll, W., & Irrek, M. (2015). The Impact of Risk Attitudes on Financial Investments. *IWH Discussion Papers, 10*. Retrived from http://nbn-resolving.de/urn:nbn:de:gbv:3:2-48596.

Irani, Z. (2010). Investment evaluation within project management: an information systems perspective. *Journal of the Operational Research Society*, *61*(6), 917-928. doi: 10.1057/jors.2010.10

Keeney, R. L., & Raiffa, H. (1993). Decisions with multiple objectives – preferences and value tradeoffs. Cambridge & New York: Cambridge University Press.

Kilinich, D., & Kobets, V. (2019, June 12-15). Support of investors' decision making in economic experiments using software tools. Paper presented at the 15th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, Kherson, Ukraine. http://ceur-ws.org/Vol-2393/paper_273.pdf.

Kobets, V., & Poltoratskiy, M. (2016, June 21-24). Using an evolutionary algorithm to improve investment strategies for industries in an economic system. Paper presented at the 12th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, Kyiv, Ukraine. http://ceur-ws.org/Vol-1614/paper_102.pdf.

Kobets, V., Yatsenko, V., Mazur, A., & Zubrii, M. (2018, May 14-17). Data analysis of private investment decision making using tools of Robo-advisers in long-run period. Paper presented at the 14th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer, Kyiv, Ukraine. http://ceur-ws.org/Vol-2104/paper_162.pdf.

Kuo, W.Y., Lin, T.C., & Zhao, J. (2015). Cognitive limitation and investment performance: Evidence from limit order clustering. *Review of Financial Studies, 28*(3), 838-875. doi: 10.1093/rfs/hhu044

Levišauskait, K. (2010). Investment Analysis and Portfolio Management. Development and Approbation of Applied Courses. Kaunas: Vytautas Magnus University.

Mon, T.Y. (2020). Study of risks assessment for implementation of QMS in MYANMAR construction industry. Proceedings on Engineering Sciences, *2*(1), 73-80. doi: 10.24874/PES02.01.008

Pangsri, P. (2015). Application of the Multi Criteria Decision Making Methods for Project Selection. *Universal Journal of Management*, *3*(1), 15-20. doi: 10.13189/ujm.2015.030103

Pujadas, P., Pardo-Bosch, F., Aguado-Renter, A., & Aguado, A. (2017). MIVES multi-criteria approach for the evaluation, prioritization, and selection of public investment projects. A case study in the city of Barcelona. *Land Use Policy*, *64*, 29-37. doi: 10.1016/j.landusepol.2017.02.014

Saaty, T. L. (2005). The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making. In J. Figueira, S. Greko, M. Ehrgott (Eds.), *Multiple Criteria Decision Analysis: State of the Art Surveys* (pp. 345-408). New York, NY: Springer.

Snihovyi, O., Kobets, V., & Ivanov, O. (2019). Implementation of Robo-Advisor Services for Different Risk Attitude Investment Decisions Using Machine Learning Techniques. *Communications in Computer and Information Science, 1007*, 298–321. doi: 10.1007/978-3-030-13929-2_15

Tariq, S., Ahmad, N., Ashraf, M. U., Alghamdi, A. M., & Alfakeeh, A. S. (2020). Measuring the Impact of Scope Changes on Project Plan Using EVM. *IEEE*, *8*, 154589-154613. doi:10.1109/ACCESS.2020.3018169

Vasovic, J. V., Radojicic, M., & Vasovic, S. (2012). Selection of investment projects in industry by application of multi-criteria decision making methods. *Metalurgia International*, *17*(6), 118-124. Retrived from https://www.webofscience.com/wos/woscc/full-record/WOS:000302988700026

Yao, D., Zhou, R., & Fan, T. (2019). Research on maturity of engineering project informatization management-As an example of Anhui Sanjian Engineering Co.,LTD. *IOP Conf. Series: Earth and Environmental Science*, *267*, 042144. doi: 10.1088/1755-1315/267/4/042144

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