Blockchain platform selection with a focus on smart contracts usage

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Abstract - The rise of blockchain technology in recent years has led to the involvement of a large number of entrepreneurs, academics and various other institutions to understand and implement this technology. A special feature of blockchain platforms are smart contracts that make them more useful and interesting for use. Therefore, there is a problem of choosing the best blockchain platform for using smart contracts according to certain criteria. In the paper, this problem is solved by applying the fuzzy PROMETHEE method, and based on PROMETHEE I and PROMETHEE II, partial and complete rank of blockchain platforms are obtained, respectively. By applying these methods, the obtained results show that the Hyperledger Fabric is the best blockchain platform for using smart contracts in relation to other platforms, according to the given criteria.

Keywords - blockchain, smart contract, multi-criteria decision-making, PROMETHEE, fuzzy numbers

I. INTRODUCTION

Blockchain, as a decentralized information transfer technology, has the potential to significantly affect all sectors that rely on intermediaries, in all industries. In 2008, a paper was published describing a peer-to-peer (P2P) version of electronic money, called Bitcoin, which allows direct payments between two parties without the mediation of a financial institution [1]. Bitcoin, as the first blockchain platform to become very successful, has created great interest in areas where building trust, transparency, security and traceability of information and transactions are important. The use of blockchain technology could prove useful in specific applications such as those where there is a requirement for interaction and agreement between multiple unreliable parties. This can be done by using the special functionality of the blockchain platforms, which are called smart contracts. With that in mind, it is important to select the best blockchain platform that supports smart contracts.

This problem can be solver using MCDM (Multi-Criteria Decision-Making) methods. MCDM is a term that describes a set of formal approaches that allow individuals or groups of decision makers to make decisions, taking into account the essentially complex nature of the problem, also all relevant criteria and overcoming all challenges that arise in choosing or creating solutions to problems [2]. Approaches based on fuzzy numbers, in combination with MCDM methods, are commonly used [3]. Linguistic values (such as poor, fair and good) are represented using fuzzy numbers. Linguistic values were mostly used because of the difficulties of finding the exact comparable data. In this paper, PROMETHEE method is proposed because of its flexibility and simplicity for the evaluation of fuzzy data.

This paper is organized as follows: Chapter II deals with understanding and explaining the basics of blockchain technology. Chapter III gives the mathematical background of the fuzzy numbers as well as the proposed fuzzy PROMETHEE method. In Chapter IV, MCDM problem is described and solved using proposed method, and also analysis of the results is given.

II. UNDERSTANDING BLOCKCHAIN TECHNOLOGY

Blockchain technology is a decentralized and distributed database that aims to record all transactions that have ever occurred in the network. The goal of such a database is to create an immutable record of all transactions and their visibility for anyone who monitors or uses the blockchain. In the following, we will present the structure, consensus protocols and working principle of blockchain technology.

A. Structure

It is a structure consisting of blocks interconnected by a chain. The chain of blocks does not exist in the real world, but in the digital one. The essence of the existence of blocks is to store transactions that have occurred in the network, while the chain refers to the cryptographic hash function that connects these blocks and makes the connection "unbreakable". One block consists of the outer header, the header, and the body of the block [4]. The outer block header identifies the blockchain platform and talks about the block size (maximum number of bytes in the block). The most important part is the block header because it contains information about the validation of the block and data about the previous block. The body of the block consists of a counter and a list of transactions.

The block header of each blockchain platform should contain the block version, the parent block hash, the nonce, the timestamp, the Merkle root, and the hash target [4]. In the process of adding a block to the chain, the most important are the hash of the parent block (the result of a hash function with the header of the previous block as input), a nonce (changed through iterations) and the target hash (fixed hash value in the network).

B. Consensus protocols

The key part in using consensus protocols is determining the node that adds the next block in the chain. As the node does not know the true identities of other nodes in the network, it cannot have the complete trust in them [5]. This protocols serve to replace trust between nodes in the network in order to achieve a common goal. There are two main groups of the consensus protocols, and those are [4] [6]: Proof-of-X (PoX) and Byzantine Fault Tolerant (BFT) algorithms.

PoX algorithms, the first group of consensus protocols, are applied mostly to the public blockchain networks. They use computational calculations to select the node that adds the next block to the chain in a random manner. The main representative of this group is the Proof-of-Work (PoW) algorithm. Here the node can publish the next block through if it solves given cryptographic problem before other nodes. When calculating the solution for this problem, it is necessary to pay attention to the nonce and the target hash. As the target hash is fixed, nonce is the only value that can be influenced in order to reach a solution and to solve a problem. Nonce is incremented through iterations and a new block header hash is computed. This new computed hash is compared with the hash target. If the block header hash is less than or equal to the target hash, it is considered that a solution is found for the cryptographic problem [4]. The main motivation of the nodes to participate in this process of solving a hard cryptographic problem is the reward they receive after successfully adding the block to the chain.

BFT algorithms, the second group of consensus protocols, are based on the protocols of communication. Nodes have equal voices and can go through multiple rounds of communication to reach consensus between them. This group of algorithms is used with private blockchain networks. This is because they are better for networks where there is a smaller number of participants compared to public. Also, they allow faster confirmation of transactions. The main representative is the Practical Byzantine Fault Tolerant (PBFT) algorithm. The main feature of this algorithm is the fact that it does not allow the number of malicious nodes (out of all nodes in the network) to be greater than 1/3 [4]. If the number of malicious nodes in the network exceeds 1/3, consensus cannot be reached.

C. The working principle

As a block is a set of transactions, in order to add a new block in the chain a larger number of new transactions are necessary to occur. Creating and adding a new block to the chain is achieved through the following four steps [4]:

1. *The occurrence of the transaction*: Potentially, if two nodes want to interact with each other and they share the same network, a new transaction can be created (e.g. cryptocurrency transfer).
2. *Transaction propagation*: Propagation in the P2P network is done by the node sending a transaction to all its neighboring nodes. Further, these nodes continue to send that transaction to their neighboring nodes. This process is repeated until each node in the network receives that transaction.
3. *Validation of the (block) transaction*: before placing the transaction in the block, it is necessary to perform its verification by the network nodes. Transaction verification refers to the validation of its cryptographic hash. Upon successful verification, the transaction received approval to be added to the block. Then, it is necessary to find an agreement between the nodes on the validity of the block, that is. the nodes must agree on the order of occurrence of transactions and the calculated hash values of the block using the consensus protocol of the network.
4. *Transaction (block) confirmation*: This represents process of adding the block in the chain. Transaction confirmation occurs when more than a majority of the network agrees that the block (containing the given transaction) is valid and then they publish that block in the chain.

D. Smart contracts

Smart contracts were first proposed in 1994 by Nick Szabo, an American computer scientist who defined them as computerized transaction protocols that execute terms of a contract [7]. Smart contracts are just programs stored in a blockchain that run when predetermined conditions are met. Typically, they are used to automate the execution of an agreement so that all participants can be immediately certain of the outcome, without any intermediary being involved. They can also be used to automate processes by triggering the next action when certain conditions are fulfilled.

Withi`e2jem5en a smart contract, there can be as many conditions as needed to satisfy the participants in terms of that the task will be completed according to a deal. When the participants agree upon all of the conditions needed, then the smart contract can be programmed by a developer (although increasingly, organizations that use blockchain for business provide templates, web interfaces, and other online tools to simplify structuring smart contracts) with a goal to implement all of the wanted conditions.

The benefits of using smart contracts [4]:

1. *Speed, efficiency and accuracy*: Once a condition is met, the contract is executed immediately. Because smart contracts are digital and automated, there is no paperwork to process which means there is no time spent on errors that often happen from manually filling in docu-

ments.

2. *Trust and transparency*: Since there is no third party involved, and because encrypted records of transactions are distributed and shared across the network, there is no need to question whether transactions have been altered for personal gain.
3. *Security:* Blockchain transaction records are encrypted, which makes them very hard to hack. Also, because each block is connected to the previous and next block, hackers would have to alter the entire chain to change a single transaction in a block.
4. *Savings:* Smart contracts are used to eliminate the need for mediators to manage transactions and their related time delays and fees.

III. FUZZY MCDM METHOD

The PROMETHEE method (Preference Ranking Organization Method for Enrichment Evaluation) is simple outranking method used in MCDM. This method can be utilized in order to find the best alternative based on an assessment of several specified criteria. Method is consisted of two phases [8]:

- The construction of outranking-relation on finite set of alternatives,
- utilization of this relation in order to give an answer to the multicriteria problem.

At first, an outranking-relation is created using pairwise comparison between alternatives based on a generalized criterion. Preference functions are defined and an outranking table is obtained. Considering for each action a leaving and an entering flow on the outranking table: a partial preorder (PROMETHEE I) or a complete preorder (PROMETHEE II) on the set of possible actions can be proposed in order to solve the decision problem.

In the paper, we will describe PROMETHEE method with the use of trapezoidal fuzzy numbers. Trapezoidal fuzzy numbers are used to express expert's opinion on alternatives regarding each criterion. Also, triangular and crisp numbers can be expressed using trapezoidal fuzzy numbers. The membership function of the trapezoidal fuzzy number can be written as [8][9]:

$$\mu(x)=\begin{cases}0, & x\le x_l-\alpha \text{ or } x_u+\beta\le x\\ 1-\dfrac{x_l-x}{\alpha}, & x_l-\alpha<x<x_l\\ 1, & x_l\le x\le x_u\\ 1-\dfrac{x-x_u}{\beta}, & x_u<x<x_u+\beta\end{cases},$$

where α and β are the left and right spread of the trapezoidal fuzzy number. In the interval $[x_l, x_u]$ values x_l and x_u are the lower and upper boundaries of the numbers that belong with certainty to the set of available values. This trapezoidal fuzzy interval is represented by the following notation, $\tilde{x}=(x_l,x_u,\alpha,\beta)$.. The algebraic operations necessary for the algorithm are defined as follows [8][9]:

$$\tilde{x}+\tilde{y}=(x_l,x_u,\alpha,\beta)+(y_l,y_u,\gamma,\delta)=(x_l+y_l,x_u+y_u,\alpha+\gamma,\beta+\delta),$$

$$-\tilde{x}=-(x_l,x_u,\alpha,\beta)=(-x_u,-x_l,\beta,\alpha),$$

$$\tilde{x}-\tilde{y}=(x_l,x_u,\alpha,\beta)-(y_l,y_u,\gamma,\delta)=(x_l-y_u,x_u-y_l,\alpha+\delta,\beta+\gamma),$$

$$\tilde{x}\cdot\tilde{y}=(x_l,x_u,\alpha,\beta)\cdot(y_l,y_u,\gamma,\delta)\approx(x_l\cdot y_l,x_u\cdot y_l,x_l\gamma+y_l\alpha-\alpha\gamma,x_u\delta+y_u\beta+\beta\delta).$$

The fuzzy PROMETHEE method is defined as [8]:

Step 1. For each criterion $\tilde{f}_k$ it is necessary to define a generalised preference function $p_k(d)$.

Step 2. Also, for all criterions the fuzzy weights are defined

$$\tilde{w}_k=(x_l^k,x_u^k,\alpha^k,\beta^k), k=1,\dots,K.$$

Step 3. For all the alternatives $a_t, a_{t'}\in A$ the fuzzy outranking-relation $\tilde{\pi}$ is defined as:

$$\tilde{\pi}:\begin{cases}A\times A\to[0,1]\\ \tilde{\pi}(a_t,a_{t'})=\sum_{k=1}^{K}\tilde{w}_k p_k(\tilde{d}(a_t,a_{t'})),\end{cases}$$

where $\tilde{d}(a_t,a_{t'})$ is fuzzy difference of evaluation between two actions defined as:

$$\tilde{d}(a_t,a_{t'})=\tilde{f}_k(a_t)-\tilde{f}_k(a_{t'})=(x_l,x_u,\alpha,\beta)-(y_l,y_u,\gamma,\delta)=(x_l-y_u,x_u-y_l,\alpha+\delta,\beta+\gamma),$$

and where $p_k(\tilde{d}(a_t,a_{t'}))$ is expressed as:

$$p_k(\tilde{d}(a_t,a_{t'}))=\Big(p_k(x_l-y_u),p_k(x_u-y_l),\big(p_k(x_l-y_u)-p_k(x_l-y_u-\alpha+\delta)\big),\big(p_k(x_u-y_l+\beta+\gamma)-p_k(x_u-y_l)\big)\Big).$$

Step 4. Measure of the strength of the alternatives $a_t \in A$, *the fuzzy leaving flow* $\tilde{\Phi}^+(a_t)$ is defined as:

$$\tilde{\Phi}^+(a_t) = \frac{1}{T-1}\sum_{t'=1,t'\neq t}^{T} \tilde{\pi}(a_t, a_{t'}).$$

Step 5. Measure of the weakness of the alternatives $a_t \in A$, the fuzzy entering flow $\tilde{\Phi}^-(a_t)$ is defined by the following expression:

$$\tilde{\Phi}^-(a_t) = \frac{1}{T-1}\sum_{t'=1,t'\neq t}^{T} \tilde{\pi}(a_{t'}, a_t).$$

Step 6. The defuzzification of the fuzzy leaving and entering flow is necessary in order to rank alternatives. The selected defuzzification approach, based on the Centre of Area (COA), is defined as:

$$x_{defuzz} = \frac{\int x\mu(x)dx}{\int \mu(x)dx} = \frac{x_u^2 - x_l^2 + \alpha x_l + \beta x_u + \frac{1}{3}(\beta^2 - \alpha^2)}{\alpha + \beta + 2x_u - 2x_l}.$$

In the following, methods PROMETHEE I and PROMETHEE II will be presented and shortly explained. The essence of the PROMETHEE methods is in determining the preference of each alternative compared to each other (pairwise comparison), according to each of the criteria, using the preference function in order to obtain the rank of alternatives, either partial or complete. The rank of an alternative based on the value of $\Phi^+(a_t)$ usually differs from the rank obtained on the basis of the value of $\Phi^-(a_t)$. PROMETHEE I by crossing the information about the values of these two characteristics, gives a partial ranking of alternatives. Possible relations of alternatives in PROMETHEE I may be preference (P^I), indifference (I^I) and incomparability (R^I) [10]. If it is not enough to get only a partial ranking of alternatives to solve a certain problem, it is necessary to apply the PROMETHEE II method. This method is used to obtain a complete ranking of alternatives. In this case, the net flow of dominance is calculated, which represents the balance between the leaving and entering flow of dominance:

$$\Phi(a_t) = \Phi^+(a_t) - \Phi^-(a_t),$$

and is used to establish a relation between alternatives. Those relations can only be preference (P^{II}) and indifference (I^{II}) [10].

IV. SOLVING MCDM PROBLEM WITH FUZZY PROMETHEE

The procedure based on the proposed algorithm for fuzzy PROMETHEE is demonstrated through the selection of the best blockchain platform for the implementation and use of smart contracts.

A. MCDM problem description

There are a growing number of technological solutions on the market that are based on blockchain technology in which global companies participate. Due to that, blockchain technology becomes very interesting for research. Illustrative example presented in this paper includes choosing a blockchain platform to use for smart contracts functionality.

In the general case, the alternatives (blockchain platforms) to choose from can be written as $A = \{a_t \mid t = 1, \ldots, T\}$. In this example, a choice is made between four alternatives ($T = 4$) , and they are: Ethereum, Hyperledger Fabric, Cardano and Waves. Alternatives (blockchain platforms) are marked as a_1 (Ethereum), a_2 (Hyperledger Fabric), a_3 (Cardano), and a_4 (Waves). a_1 (Ethereum) is a decentralized blockchain platform that establishes a peer-to-peer network and it is most commonly known for its native cryptocurrency (ETH) as well as the popularization of smart contracts and Non-Fungible Tokens (NFTs) [11]. a_2 (Hyperledger Fabric), an open source project from the Linux Foundation, is the highly modular and configurable blockchain framework intended as a foundation for developing enterprise-grade applications and industry solutions [12]. a_3 (Cardano) aims to be the most scalable and environmentally sustainable blockchain platform through use of PoS consensus protocol [13], as opposed to the energy-intensive PoW currently used by Bitcoin and Ethereum. a_4 (Waves) is a blockchain platform that focuses on scalability, interoperability, environmental friendliness, and makes it easy to create custom crypto tokens (known as smart assets) and launch smart contracts that power a range of decentralized applications (dApps) [14].

In addition to the mentioned and briefly explained alternatives, it is necessary to state and explain the criteria according to which their comparison will be performed. In the general case, the set of selected criteria can be written as $F = \{f_k \mid k = 1, \ldots, K\}$. This example considers fourteen criteria ($K = 14$), including: maturity (f_1), scalability (f_2), decentralization (f_3), transparency (f_4), immutability (f_5), interoperability (f_6), block time (f_7), supporting cooperation and data exchange with other software (f_8), electricity consumption (f_9), number of programming languages (f_{10}), virtual machine testing (f_{11}), standardization and support (f_{12}), costs of use (f_{13}), and migration (f_{14}). The criteria are divided into two groups: characteristics of the blockchain platform and characteristics of the smart contracts. The first 9 criteria belong to the first group, while the remaining 5 criteria belong to the second group. f_1 (maturity) is an assessment of the maturity of the blockchain platform based on years of existence, market share, number of transactions and users, etc. f_2 (scalability) refers to supporting a large number of nodes and transactions in the blockchain network. f_3 (decentralization) describes the transfer of control and decision-making from a centralized entity (individual, organization or group) to a distributed blockchain network. f_4 (transparency) refers to the availability and traceability of data and transactions in the blockchain to everyone and at any time. f_5 (immutability) is a feature that in the blockchain remains a permanent and unchanged history of all transactions that have taken place. f_6 (interoperability) refers to the ability of different blockchain platforms to exchange and use data with each other. f_7 (block time) represents the mean time required to add a new block to the chain, which means that the transaction is considered to be permanently registered (expresses in seconds). f_8 (supporting cooperation and data exchange with other software) considers collaboration and data exchange across different application programming interfaces (APIs). f_9 (electricity consumption) depends on the consensus protocol used by the blockchain platform (e.g. PoW generates the highest, while the PoS generates the lowest consumption). f_{10} (number of programming languages) represents the number of programming languages that can be used to program smart contracts, where the focus is on the official programming languages of the blockchain platform. f_{11} (virtual machine testing) refers to possibility of running and testing smart contracts in testing environment (essential for developers, not end users). f_{12} (standardization and support) represents the existence of a large community that contributes to the development of smart contracts, the elimination of security problems in code that hackers can exploit, the existence of documentation for learning, understanding, etc. f_{13} (costs of use) refers to the costs of creating, running and using a smart contract in a blockchain network (mostly depends on the size of the smart contract, i.e. the amount of bytecode of the smart contract). f_{14} (migration) represents the possibility of migrating a smart contract from one blockchain platform to another.

Also, in addition to alternatives and criteria, it is necessary to determine the weights for each of the criteria. The set of weights can be written as $\widetilde{W} = \{\widetilde{w}_k \mid k = 1, \dots, K\}$. For this case, triangular fuzzy numbers were used to represent weights for each criterion. Here, triangular fuzzy numbers are represented as a specific case of trapezoidal fuzzy numbers. The linguistic values and the corresponding triangular fuzzy values for each criterion are given in Table 1.

Table 1. Linguistic values and corresponding fuzzy numbers

Linguistic values	Fuzzy numbers
Very Poor (VP)	(0,0,0,0.15)
Poor (P)	(0.2,0.2,0.1,0.1)
Medium Poor (MP)	(0.3,0.3,0.1,0.1)
Fair (F)	(0.5,0.5,0.2,0.2)
Medium Good (MG)	(0.7,0.7,0.1,0.1)
Good(G)	(0.8,0.8,0.1,0.1)
Very good (VG)	(1,1,0.15,0)

Generally speaking, expert assessments can be used to determine the weights of the criteria, where a set of experts can be written as $E = \{E_i \mid i = 1, \dots, N\}$. Each expert gives his assessment for each of the criteria using linguistic value. We will assume that the significance of each of the experts involved in decision-making process is the same. After that, it is necessary to aggregate expert assessments which gives the final weights ($\widetilde{w}_k$) of each of the criteria. This can be achieved by using the following equations:

$$\widetilde{w}_k^i = \left(x_{uk}^i, x_{lk}^i, \alpha_k^i, \beta_k^i\right), i = 1, \dots, N,$$

$$\widetilde{w}_k = \left(\frac{1}{N}\sum_{i=1}^{N} x_{uk}^i, \frac{1}{N}\sum_{i=1}^{N} x_{lk}^i, \min_i \alpha_k^i, \max_i \beta_k^i\right),$$

where $\widetilde{w}_k^i$ are fuzzy numbers that correspond to experts assessments.

For the purposes of the example in this paper, three experts ($N = 3$) gave their assessments for each of the criteria whose aggregation gives the final weights. These values, represented by triangular fuzzy numbers, are given in Table 2.

Table 2. Aggregated weight of the criteria assessed by the experts along with p and q values for preference function

Criteria	Aggregated weight	p	q
f_1	(0.93,0.93,0.23,0.07)	0.10	0.07
f_2	(0.77,0.77,0.17,0.13)	0.11	0.08
f_3	(0.77,0.77,0.17,0.13)	0.04	0.03
f_4	(0.70,0.70,0.10,0.10)	0.05	0.04
f_5	(0.87,0.87,0.17,0.13)	0.04	0.03
f_6	(0.63,0.63,0.33,0.17)	0.06	0.04
f_7	(0.27,0.27,0.17,0.13)	21.08	14.95
f_8	(0.43,0.43,0.23,0.27)	0.10	0.08
f_9	(0.73,0.73,0.13,0.17)	0.11	0.08
f_{10}	(0.50,0.50,0.20,0.20)	0.71	0.50
f_{11}	(0.30,0.30,0.10,0.10)	0.36	0.25
f_{12}	(0.93,0.93,0.23,0.07)	0.08	0.06
f_{13}	(0.80,0.80,0.10,0.10)	0.10	0.07
f_{14}	(0.63,0.63,0.33,0.17)	0.21	0.15

Lastly, before applying the fuzzy PROMETHEE method described in Chapter III, it remains to fill in the decision-making table by entering the values of alternatives according to each of the criteria. Values from decision-making table can be written as $\widetilde{X} = \{\widetilde{x}_{tk} = f_k(a_t) \mid t = 1, \dots, T;\ k = 1, \dots, K\}$. In this example, the values of the decision-making table are entered through two approaches. The second approach was mostly used in the considered example, as the first approach was used only for f_7, f_{10} and f_{11}. The first approach is to collect values from the relevant literature ([15][16][17][18][19][20]) for all alternatives according to criteria f_7, f_{10} and f_{11}. These values are exact or crisp values. The second approach is to enter the value through the evaluation of each alternative according to certain (remaining) criteria by experts. Evaluation by experts is performed using linguistic values (Table 1). After that, the expert assessments are aggregated to obtain the final values ($\tilde{x}_{kt}$) for the decision-making table using the following equations:

$$\tilde{x}^i_{kt} = \left(x^i_{ukt}, x^i_{lkt}, \alpha^i_{kt}, \beta^i_{kt}\right), i = 1, \dots, N,$$

$$\tilde{x}_{kt} = \left(\frac{1}{N}\sum_{i=1}^{N} x^i_{ukt}, \frac{1}{N}\sum_{i=1}^{N} x^i_{lkt}, \min_i \alpha^i_{kt}, \max_i \beta^i_{kt}\right),$$

where $\tilde{x}^i_{kt}$ are fuzzy numbers that correspond to experts assessments.

It should be noted that all criteria are maximized, except criterion f_7 which is minimized. Using these two approaches, the final values of the decision-making table for each alternative for each of the criteria were obtained (Table 3).

The decision-making table is complete, i.e. alternatives and criteria have been entered and the weights of criteria and values in the table have been determined. It is now possible to apply the fuzzy PROMETHEE method and perform the analysis of the obtained results. Linear criterion with preference and indifference area is used as the preference function for all criteria in this example. Thresholds of indifference (p) and preference (q) for this criterion are shown in Table 2.

B. Result analysis

By applying the fuzzy PROMETHEE method over the decision-making table, the defuzzified values for entering, leaving and net flow are shown in Table 4.

Table 4. Defuzzified values of the leaving, entering and net flow

	a_1	a_2	a_3	a_4
$\Phi^-(a_t)$	3.1265	5.4440	1.6339	1.7525
$\Phi^+(a_t)$	2.7314	1.1838	3.4309	3.9934
$\Phi(a_t)$	0.3951	4.2602	-1.7970	-2.2409

Using values from Table 4, it is possible to apply PROMETHEE I and PROMETHEE II methods. Firstly, we will discuss the application of the PROMETHEE I method, which provides a partial rank of alternatives. Basically, the higher the leaving flow (Φ^+ value) and the lower the entering flow (Φ^- value) the blockchain platform is better for using smart contracts. By analyzing the results, the following relation between alternatives can be established $a_2\ P^I\ a_1\ P^I\ a_3\ R^I\ a_4$. In other words, we see that a_2 (Hyperledger Fabric) is the best blockchain platform (preferred over the rest), then a_1 (Ethereum) which is preferred over platforms a_3 (Cardano) and a_4 (Waves), but worse than a_2 (Hyperledger Fabric), and that a_3 (Cardano) and a_4 (Waves) are the worst and incomparable. Secondly, in order to get a clear picture of alternative relations, we use the PROMETHEE II method. This method provides a complete rank of alternatives. The higher the net flow (Φ value) the blockchain platform is better for using smart contracts. By comparing values between alternatives, we get the following relation $a_2\ P^{II}\ a_1\ P^{II}\ a_3\ P^{II}\ a_4$. From this relation, we can see that that a_2 (Hyperledger Fabric) is the best blockchain platform (preferred over the rest), then a_1 (Ethereum) which is preferred over platforms a_3 (Cardano) and (Waves), then (Cardano) and finally a_4 (Waves). a_2 (Hyperledger Fabric) is determined to be the best blockchain platform out of all platforms considered in this paper. Also, it is determined that a_4 (Waves) is the worst platform (Fig. 1).

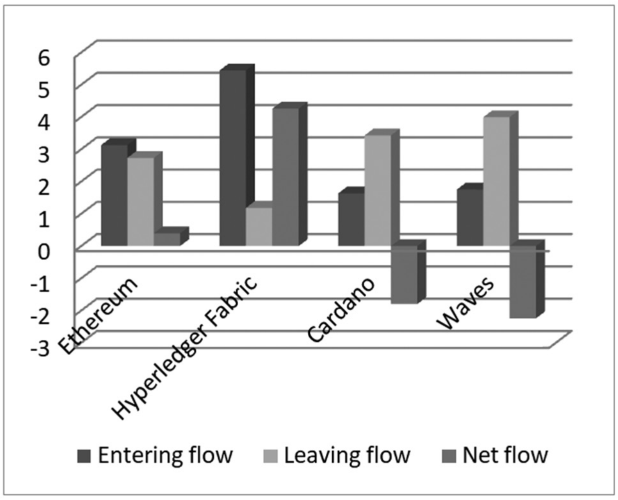

Fig. 1. Fuzzy PROMETHEE I and II partial and complete rank

V. CONCLUSION

Over the years, blockchain technology has become an increasingly relevant for study, testing and implementation attempts. This is mostly because of the smart contracts. Therefore, the number of blockchain platforms offering smart contract functionality has grown significantly. As a result, the goal is to select the best blockchain platform (alternative) for using smart contracts according to selected criteria. To solve this problem, the fuzzy MCDM method has been used. This paper proposes the fuzzy PROMETHEE method based on trapezoidal fuzzy numbers as a possible solution. Using PROMETHEE I and PROMETHEE II methods, partial and complete rank of the blockchain platforms were obtained, respectively. The obtained results of complete rank shows that Hyperledger Fabric is the best ranked alternative. This tells us that this blockchain platform is the most suitable for using and developing smart contracts. This is an important conclusion that may be of use to various companies that want to implement blockchain technology and its functionality of smart contracts, but are not sure which blockchain platform to choose.

Future research may involve considering a higher number of alternatives and/or criteria, a higher number of experts, or the use of other MCDM methods to compare their results.

Table 3.Aggregated values of the decision-making table assessed by the experts

$\tilde{X}$	a_1	a_2	a_3	a_4
$\tilde{f}_1$	(1,1,0.15,0)	(0.80,0.80,0.10,0.10)	(0.37,0.37,0.17,0.33)	(0.63,0.63,0.33,0.17)
$\tilde{f}_2$	(0.50,0.50,0.20,0.20)	(0.87,0.87,0.17,0.13)	(0.77,0.77,0.17,0.13)	(0.73,0.73,0.13,0.17)
$\tilde{f}_3$	(0.87,0.87,0.17,0.13)	(0.83,0.83,0.23,0.17)	(0.87,0.87,0.17,0.13)	(0.93,0.93,0.23,0.07)
$\tilde{f}_4$	(0.77,0.77,0.17,0.13)	(1,1,0.15,0)	(0.73,0.73,0.13,0.17)	(0.77,0.77,0.17,0.13)
$\tilde{f}_5$	(0.77,0.77,0.17,0.13)	(0.87,0.87,0.17,0.13)	(0.93,0.93,0.23,0.07)	(0.73,0.73,0.13,0.17)
$\tilde{f}_6$	(0.80,0.80,0.10,0.10)	(1,1,0.15,0)	(0.77,0.77,0.17,0.13)	(0.80,0.80,0.10,0.10)
$\tilde{f}_7$	(14,14,0,0)	(0.2,0.2,0,0)	(20,20,0,0)	(60,60,0,0)
$\tilde{f}_8$	(0.80,0.80,0.10,0.10)	(0.80,0.80,0.10,0.10)	(0.50,0.50,0.20,0.20)	(0.70,0.70,0.10,0.10)
$\tilde{f}_9$	(0.50,0.50,0.20,0.20)	(0.87,0.87,0.17,0.13)	(0.80,0.80,0.10,0.10)	(0.70,0.70,0.10,0.10)
$\tilde{f}_{10}$	(3,3,0,0)	(2,2,0,0)	(2,2,0,0)	(1,1,0,0)
$\tilde{f}_{11}$	(1,1,0,0)	(1,1,0,0)	(0,0,0,0)	(0,0,0,0)
$\tilde{f}_{12}$	(1,1,0.15,0)	(0.93,0.93,0.23,0.07)	(0.37,0.37,0.17,0.33)	(0.63,0.63,0.33,0.17)
$\tilde{f}_{13}$	(0.57,0.57,0.27,0.23)	(1,1,0.15,0)	(0.77,0.77,0.17,0.13)	(0.87,0.87,0.17,0.13)
$\tilde{f}_{14}$	(1,1,0.15,0)	(0.80,0.80,0.10,0.10)	(0.27,0.27,0.17,0.13)	(0.01,0.01,0.01,0.29)

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