

Multi-Criteria Evaluation Of Blockchain Platforms For Web Applications Using An Integrated Fuzzy AHP-TOPSIS Approach

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Abstract. Significant interest in blockchain based web applications has been generated by the sudden development of Web 3.0. However, this interest creates a difficult multi-criteria decision-making process for which there are no definitive answers to several key questions regarding how best to select the most suitable blockchain technology for use with decentralized web applications. These include the identification of relevant technical, economic, and ecosystem factors that will be subject to varying degrees of uncertainty. In order to address these issues, this research introduces a new hybrid fuzzy Analytic Hierarchy Process (AHP)-Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), for evaluating and ranking the suitability of different blockchain technologies for use as infrastructure for web applications. Subjective expert evaluations of alternative blockchain platforms will be quantified by fuzzy triangular numbers representing linguistic terms that are used to represent the level of ambiguity involved when experts make subjective evaluations. The fuzzy AHP methodology will be applied to identify the relative importance of five key factors including throughput, transaction costs, security, scalability and developer ecosystem support to the selection of a blockchain platform for web application infrastructure. Additionally, the fuzzy TOPSIS methodology will be used to identify the degree of similarity between each candidate blockchain platform and the fuzzy ideal solutions. A case study that compares Ethereum, Polygon, Binance Smart Chain, Solana, and Hyperledger Fabric will be presented to demonstrate the practical application of the proposed framework. The results of this analysis will illustrate the tradeoffs involved in selecting one blockchain platform over another and provide organizations with a clear, consistent, and replicable method for selecting blockchain infrastructure for their web applications. Finally, the implications of this research for managers, its limitations, and opportunities for future research will be discussed.

Keywords: Blockchain Web Applications, Analytic Hierarchy Process (AHP), TOPSIS, Fuzzy.

1. Introduction

Blockchain Technology, which was originally created to enable cryptocurrency transactions, has become the foundation for decentralized web applications (dApps) in many sectors, including finance, supply chain management, healthcare, and governance [1]. This rapid expansion means developers and architects who want to build dApps will find themselves confronted by a wider variety of blockchain platforms than ever before. There are some examples of leading platforms, which are public permissionless networks; permissioned enterprise frameworks; and everything in between [2]. For example: there are Ethereum, Polygon, Solana, BNB Chain (also known as Binance Smart Chain); and Hyperledger Fabric — just to name a few. Platforms also offer different levels of capabilities, and each platform has its own advantages and disadvantages; for instance, some platforms focus on decentralization and developer flexibility, while others focus on high throughput, low-cost transactions, or enterprise-level security. Therefore, the first step in building a successful dApp is selecting the right blockchain platform — and doing so successfully is a critical strategic decision.

The task of selecting a blockchain platform is an inherently multi-criteria decision-making problem. To select the most suitable blockchain platform for a specific dApp, a large set of various technical and ecosystem criteria must be taken into consideration. Examples of these types of criteria include: performance-related metrics (throughput and latency); security and robustness of the consensus mechanism; scalability; interoperability; costs (development costs); and maturity of the ecosystem (support from community, quality of developer tools, etc.) [3]. Many of these criteria are conflicting with one another; i.e., choosing to improve one criterion (for example, scalability) may adversely affect others (for example, decentralization and security) [4]. As a result, there is no blockchain platform that is clearly better than any other in every way, and therefore trade-offs are always necessary. Moreover, as the number of available blockchain platforms and the number of evaluation factors grow, the complexity of the decision process will grow to the point where even the simplest comparisons will be difficult to make using an informal method. Therefore, it becomes clear that, in order to provide a systemic solution to the problem of selecting a blockchain platform for dApps, it is necessary to apply a structured multi-criteria model to evaluate the various competing blockchain platforms [3]. The use of a structured multi-criteria model for evaluating blockchain platforms will allow experts to express their knowledge formally and objectively, and to take into consideration all of the important criteria for making the decision about which platform to choose.

Limitations of existing research and the necessity of fuzzy MCDM in evaluating blockchain platforms: Many studies and benchmarking efforts have been conducted to evaluate and compare blockchain systems, however, typically based on either qualitative assessments or single metrics that do not enable the use of an integrated evaluation system. Consequently, evaluations of blockchain systems generally remain highly subjective and/or limited to a very narrow focus, for example, only throughputs or security. Few works have utilized a comprehensive multi-criteria decision making (MCDM) framework for selecting a blockchain system. Consequently, developers may experience difficulty in determining their best option, due to the lack of integration and transparency of the various pieces of information. A systematic MCDM approach can bridge this gap in the literature by providing a complete and transparent comparison. In fact, case studies have demonstrated that utilizing a decision model yields substantially more insight and provides a more detailed and prioritized listing of options than does ad hoc individual research; it also results in reduced time and effort required. Therefore, a structured analysis not only enhances the quality of decisions, but also their efficiency. The process of selecting a blockchain system, especially under conditions of high levels of uncertainty and fast evolving technology, would greatly benefit from the application of MCDM.

In order to address these issues, this paper uses an integrated fuzzy AHP-TOPSIS approach to evaluate and prioritize blockchain systems for dApp development. We employ fuzzy versions of Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) since the decision environment contains fuzzy and vague judgments from the decision makers regarding the preference for each of the criteria and the relative position of each of the alternative solutions. The fuzzy AHP is used to calculate the weights of the criteria derived from fuzzy pairwise comparisons made by the decision maker, i.e., in linguistic terms such as "much more" and "a little less", which are then converted into fuzzy numbers [5]. The use of fuzzy AHP allows the natural vagueness and uncertainty present in human judgment and preference to be captured, thereby enhancing the realism of the weighting process [6]. The output of the fuzzy AHP process will be a set of importance weights representing the collective priority of Web3 architects under conditions of uncertainty. Subsequently, fuzzy TOPSIS will be used to assess the five candidate systems against the weighted criteria. TOPSIS works by measuring the distance between each alternative and an ideal solution, and the fuzzy

version of TOPSIS allows for the inclusion of uncertain/qualitative performance ratings of the systems on each criterion. Combining the fuzzy weights obtained via fuzzy AHP with fuzzy performance ratings in fuzzy TOPSIS enables the determination of a definitive ranking of the systems from most to least appropriate for dApp development. The hybrid fuzzy AHP-TOPSIS methodology has the advantage of addressing both parts of the decision problem: it provides a systematic approach to determine the relative priority of the criteria and it provides a final selection among the alternatives, while enabling the ambiguity in the inputs from the decision makers and the performance ratings of the systems to be accommodated. The application of fuzzy MCDM will allow for a uniform and transparent decision process that can effectively capture the complex trade-offs in the process of selecting a blockchain system.

1.1. Objective and contributions:

This paper has three main objectives. First, the study evaluates five of the most widely used blockchain platforms (Ethereum, Polygon, Solana, BNB Chain, and Hyperledger Fabric) for potential use as infrastructure for generalized purpose decentralized web applications. Second, from the perspective of the Web3 developer and architect, the study identifies a comprehensive set of evaluation criteria including both technological properties and ecosystem characteristics that are relevant to successful scalable and cost-effective deployment of decentralized application (dApps). Third, the study uses fuzzy AHP to assign relative weights to each of the evaluation criteria and fuzzy TOPSIS to rank the candidate blockchain platforms with respect to how well each fulfills the evaluation criteria. Therefore, this study contributes to the state of knowledge and practice in four ways: (1) it models the blockchain platform selection problem as a multiple criteria decision-making model where fuzzy logic is applied to account for uncertainty and linguistic assessments; (2) it provides quantitative importance weights for both technical and ecosystem characteristics (i.e., throughput, security, development cost, community support); (3) it presents a data driven ranking of the blockchain platforms evaluated, providing a structured representation of each platform's relative strengths and weaknesses compared to other platforms; and (4) it demonstrates the effectiveness of an integrated fuzzy AHP-TOPSIS methodology in evaluating blockchain platforms in a Web3 context, which fills a gap in current comparative studies that lack formal MCDM modeling. As such, the results of this research provide actionable insights for blockchain developers and decision makers who wish to make more informed decisions when selecting blockchain platforms. Ultimately, this research aims to facilitate the creation of decentralized applications that meet the performance, security, and cost requirements of its users through the use of a rigorous evaluation methodology for selecting blockchain infrastructure.

2. Literature Review

2.1. Blockchain Technology Overview and Limitations

Blockchain technology has been identified as a revolutionary force in both business and computing environments, and it has been characterized as one of the key foundations for "internet 2.0" due to the way that it provides users with the ability to conduct transactions directly without intermediaries, and the way that these transactions are recorded as part of an unalterable ledger of transactions (e.g., smart contracts) that is accessible to all parties participating on the blockchain network [7,8,9]. The two primary components of blockchain technology that make this possible are the distributed peer-to-peer consensus mechanism, which enables a large number of computers to work together to validate each other's calculations, and the immutable ledger of transactions (e.g., smart contract

executions), which makes it impossible for anyone to alter or delete any record of transactions that have occurred on the blockchain [10,11,9]. It is because of the transparency provided by the immutable ledger, and the trust that exists among parties on a blockchain network even when there is no pre-existing relationship between them, that blockchain is being touted as a transformative force across a wide range of industries from financial services to supply chain management. However, with the advent of blockchain technology comes several technical barriers to widespread use of blockchain technology. First and foremost, scalability and throughput are a major concern [12,13,14]. For example, public blockchain networks are capable of processing a small fraction of the number of transactions per second than their legacy counterparts. To be specific, some public blockchain networks are able to process fewer than 400 transactions per second on average, while traditional payment networks such as Visa are able to process thousands of transactions per second. As such, these differences highlight the performance limitations of the first generation of blockchain technologies in high volume, real-time applications. Another technical barrier to widespread use of blockchain technology is privacy. Blockchain systems inherently sacrifice privacy for transparency. Because all parties on a blockchain system have access to the shared ledger, data transparency on a blockchain system can result in an erosion of privacy for all users regarding their transaction details [15]. Although the use of cryptographic techniques such as hashing and digital signatures ensures the integrity and authenticity of records on a blockchain system, maintaining the confidentiality of data on a public ledger is difficult. As such, while blockchain technology has tremendous potential for disruption, there are significant technical barriers to its broader adoption including through-put, latency, and data confidentiality. These technical barriers have motivated the development of many different blockchain technologies and variants of those technologies.

2.2. Blockchain Platforms: Types and Comparative Analyses

For over ten years, a variety of ecosystems of blockchain platforms have developed with different trade-offs among competing goals. Blockchain platforms can be generally categorized based upon their governance models (i.e., who is allowed to participate and how decisions are made). Zheng et al. (2018), for example, identify three fundamental categories of blockchain systems (public, consortium and private) and assess them across several dimensions of quality [10]. Public or permissionless blockchains (such as Bitcoin or Ethereum) allow anyone to both join and verify transactions. The decentralized nature of this approach results in greater security, and reduced likelihood of censorship but also results in decreased performance and increased resource usage. Private or permissioned blockchains restrict membership to previously known entities and reduce the level of decentralization in favor of increased efficiency, performance (in terms of throughput), and data protection. Some examples of the differences in characteristics between public, consortium and private blockchains include the consensus algorithm (e.g., probabilistic consensus algorithms such as Proof of Work or Proof of Stake), the permissions associated with reading/writing data, the degree of centralization of the network and the efficiency of the network [9,16,17]. For example, public networks will typically utilize probabilistic consensus algorithms (such as Proof of Work or Proof of Stake) to ensure security and prevent censorship, while consortium networks may employ faster Byzantine Fault Tolerance or authority-based consensus algorithms because they are assuming that the participating parties are inherently trustworthy. A number of researchers have compared the different types of blockchain platforms using multiple criteria including performance and trust metrics to assist in selecting the most suitable platform. One representative study is Wieninger et al. (2019), which compares public versus private blockchains across seven criteria: transaction cost, throughput, confirmation latency, system

trustworthiness, scalability, maintenance effort, and openness of access [18]. The authors used a relative rating system (high/medium/low) for each criterion to illustrate, for example, that public chains have high levels of openness and trust due to their decentralized nature but low throughputs and high latencies; and conversely, permissioned chains have high throughputs and low latencies but low levels of openness and trust. Similarly, decision-making frameworks have been created to help determine whether and what kind of blockchain would be the most suitable for a particular project [19]. An example of one such framework is a decision tree introduced by Wüst and Gervais (2018) that asks a series of questions (for example regarding shared write access and the assumptions of trust) to determine what type of ledger would best suit a particular project [20]. The comparative studies mentioned above demonstrate that there is no single blockchain platform that meets the needs of all projects; rather, there are inherent trade-offs between decentralization and performance, security and efficiency, openness and control in the different design options available for blockchain platforms.

In addition to architectural classification, another significant area of comparison in the body of literature is the consensus algorithm used to maintain the integrity of blockchain ledgers and its impact on both performance and security. In an effort to improve upon one or more dimensions of the blockchain trilemma (scalability, security, and decentralization), a variety of consensus algorithms have been designed since Bitcoin's original Proof of Work; examples include PBFT (Practical Byzantine Fault Tolerance), PoA (Proof of Authority), and PoS (Proof of Stake) as they achieve high transaction throughput and/or low latency in permissioned environments where a trusted intermediary exists [21,9]; however, while PBFT and PoA provide high levels of security and throughput in semi-trusted environments, they do so at the expense of the ability to scale to large numbers of participants, and are limited to permissioned networks. On the other hand, PoS requires validators to "stake" cryptocurrency for validating transactions rather than expend computational resources in order to reduce the energy consumption associated with Proof of Work (PoW); however, this method of consensus introduces several new types of attacks that must be mitigated (e.g., nothing-at-stake, cartel formation) to ensure security. Comparative analysis has studied the various consensus mechanisms and their respective energy efficiencies, fault-tolerant properties, and robustness in the face of attacks [8,17]; for example, many studies have analyzed the trade-offs between governance and consensus functions, highlighting the fact that decisions regarding which consensus mechanism to use (e.g., PoW vs. PoS) have implications not only for technical performance but also for network governance (e.g., who influences block proposal/validation). As such, the literature provides a rich comparative analysis of the design space for blockchain platforms; ranging from high level architectural classification (public/private/hybrid) to low level consensus algorithm, researchers have identified and compared the full range of design choices and their implications on scalability, security, and decentralization.

2.3. Taxonomies and Evaluation Frameworks in Prior Work

To navigate this constantly shifting terrain, researchers have started building taxonomies and frameworks to make sense of blockchain platforms and their applications. These taxonomies act like structured maps: they classify features and design choices so that academics and practitioners can actually compare one blockchain solution against another instead of talking past each other. Figure 1 presents that these efforts reflect an understanding that blockchain is not a monolithic technology: it is a bundle of design facets that can be configured in different ways, and a taxonomy helps isolate those facets for analysis.

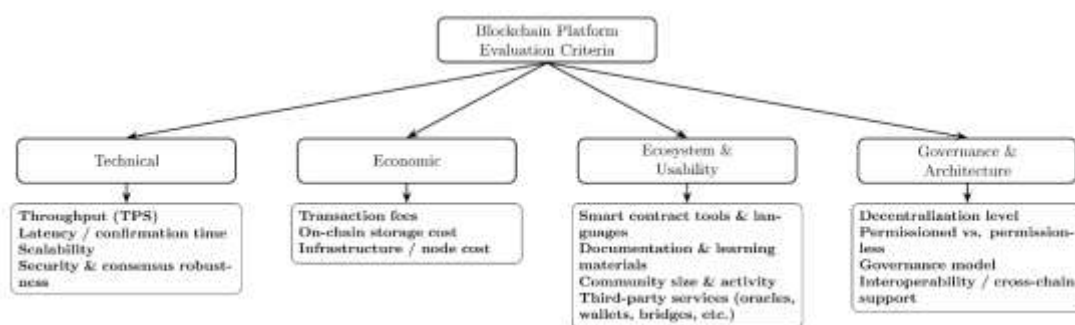


Fig 1. Taxonomy of blockchain platform evaluation criteria synthesized from prior studies.

Xu et al. (2018) offer a well-known example, slicing blockchain architecture into five core design decision domains: whether the system creates a new blockchain or reuses an existing platform, which consensus protocol is chosen, how that protocol is structured, who is allowed to participate (public vs. private), and what data structure underpins the ledger [22]. Once the space is organized this way, it becomes much easier to see how a single choice—say, adopting a public chain with a particular consensus mechanism—ripples through to security and scalability. Yeow et al. (2017) take a related but broader angle, proposing a taxonomy of decentralized consensus systems that covers both blockchain-based and non-blockchain distributed ledger technologies [23]. Their framework singles out three foundational dimensions—data structure, consensus ledger scalability, and transaction model—to line up different consensus approaches and weigh their respective strengths and weaknesses. Put together, these efforts lean on the same core insight: “blockchain” isn’t one thing. It’s a configurable bundle of design facets, and a careful taxonomy pulls those facets apart so they can be examined, compared, and argued about in a more precise way.

Taxonomies have been developed specifically for particular aspects or application domains of blockchain. For example, Tasca and Tessone (2017) identified a number of common components of blockchain systems (including identity management, tokenization, transaction capability, consensus mechanism, reward system, and security/privacy) as a foundation for categorizing systems [16]. Labazova et al. (2019) proposed a taxonomy that links the technical characteristics of blockchain systems to their application areas, to assist in identifying which type(s) of blockchain are best suited for a particular use case [24]. The existence of multiple domain-specific taxonomies illustrates the broad range of research being conducted in the field of blockchain technology, and the fact that different sectors place emphasis on different aspects of blockchain technology (e.g. financial services vs. IoT and supply chains). In addition to categorizing blockchain types, Zheng et al. (2018) identified six essential quality attributes for evaluating blockchain systems, which include how consensus is determined; who has read permission; the degree of immutability of the blockchain; overall efficiency; the degree of centralization; and the characteristics of the consensus process [10]. The identification of these quality attributes provides a comprehensive lens through which to compare blockchain platforms, moving beyond raw performance metrics to incorporate governance (centralization, permissions) and security (immutability, soundness of consensus) considerations.

Although Monrat et al. (2024) were able to develop a strong framework to guide development of blockchain taxonomies, there are still areas in which there is little research about the integration of evaluation frameworks for blockchain systems; specifically in terms of governance and the cross-cutting trade-offs between different

features of blockchain systems. The majority of previous studies developed taxonomies primarily focused on either technical aspects or applications of blockchain technology, but paid relatively little attention to how the organization's governance structure influences its selection of blockchain systems. As such, the authors developed a taxonomy guideline for blockchain systems that has a primary focus on evaluating governance related trade-offs [8] when selecting a blockchain system. This will help evaluate trade-offs between governance and other attributes of blockchain systems including the consensus mechanism, energy consumption, performance, and security, while also evaluating how each of these trade-offs can be impacted based on the governance structure of a particular organization. The study is intended to assist designers/architects in identifying the most appropriate configuration of a blockchain system (i.e. whether it should be permissionless or permissioned, high security vs. high performance), to meet the objectives of a particular use case. Their work demonstrates a shift in the literature away from technical only evaluations and toward a more systemic approach to the evaluation of blockchain technologies including broader system characteristics (such as governance, incentives, etc.) in addition to technical characteristics. A holistic view of blockchain systems is critical because many real-world deployments involve a combination of both technical feasibility and governance considerations.

There is an extensive variation in the criteria used to assess the blockchain platforms studied within the literature and as such there is no consistency and at times there is an omission of significant factors relative to each respective study's assessment criteria. Technical performance metrics commonly utilized for assessing blockchain platforms' capabilities include through-put (i.e., transactions per second) and latency (which reflect the upper bounds of scalability for each platform). Consensus mechanisms' robustness has been viewed by all authors as a universal security aspect. In addition, many authors compare consensus algorithms and different networks; e.g., whether or not a blockchain platform is permissionless or permissioned, are two major ways of evaluating the distinction between various blockchain platforms [25]. Enterprise adoption of blockchain technology will be heavily reliant on cost and resource efficient aspects (e.g. transaction fees and energy usage). As a result of increasing recognition of the importance of development related factors, development toolkits available for development of blockchain applications, API support, documentation, community support and the ease-of-use of smart contract languages can significantly impact the suitability of a blockchain platform. Table 1 compares major blockchain platforms that are examples. Examples include Ethereum and Solana which represent popular Layer-1 networks for Web3 applications, Hyperledger Fabric as an Enterprise Platform, and Polkadot as a Multi-Chain Framework.

Table 1. Representative blockchain platforms and their key characteristics

Platform	Type / Network	Consensus Mechanism	Smart Contract Support	Notable Features
Ethereum	Public, permissionless	Proof of Stake (Nakamoto-style)	Yes (Solidity, EVM)	Mature dApp ecosystem; highly decentralized; ~15 TPS base layer (scales via Layer-2); higher gas fees.

Solana	Public, permissionless	Proof of Stake + Proof of History	Yes (Rust, C/C++ via BPF)	High throughput (1,000+ TPS); low fees; monolithic design favors speed over decentralization.
Hyperledger Fabric	Private/ Consortium (permissioned)	Pluggable BFT or RAFT consensus	Yes (Chaincode in Go/Java/etc.)	Enterprise-focused modular architecture; controlled governance; performance in hundreds TPS range; no native cryptocurrency.
Polkadot	Public, permissionless (multi-chain)	Nominated Proof of Stake (NPoS)	Yes (Wasm smart contracts on parachains)	Multi-chain interoperability; parallel transaction processing (theoretically very high aggregate TPS); on-chain governance mechanism.

Many prior comparative studies focused on subsets of the aforementioned criteria and platforms, with respect to the scope of the study. The example of Kuo et al. (2019), presented a systematic comparison of the security and performance of the Ethereum platform and Hyperledger Fabric in the health care industry [26]. Other researchers have cataloged many platforms -- Connors and Sarkar (2023), reported more than 65 active platforms and a rapidly expanding number of developers -- but limited their evaluations to several criteria or usability for specific uses cases [27]. The variation in the number of criteria sets being evaluated (range from fewer than 10 criteria in some decision tree approaches to greater than 100 in large-scale frameworks), creates challenges when comparing results among studies. There is no standard set of evaluation criteria, each study determines what criteria will be used in relation to the context of the study and may ignore other important factors such as governance and developer experience

2.4. Gaps in Current Literature

Three major shortcomings exist with respect to previous research. First, there is no fuzzy AHP-TOPSIS framework, which has been developed exclusively for Web3-based web application development. Fuzzy AHP and TOPSIS have both been utilized separately in prior studies; fuzzy AHP has been utilized for weighting in some studies, while TOPSIS has been utilized for ranking in other studies. However, they have generally been implemented across different domains or were based on an evaluation of a general platform selection rather than on developing web applications. No prior study was identified, where fuzzy AHP was employed for weighting, and fuzzy TOPSIS was employed for ranking when evaluating blockchain platforms for building decentralized web applications. Second, the existing body of literature does not consistently adopt all relevant criteria; various studies have emphasized different criteria and therefore have resulted in multiple disparate evaluation perspectives. For example, some earlier or domain-specific frameworks include only a limited number of criteria; e.g., only performance and security. Other

frameworks include extensive lists of criteria that are difficult to evaluate. There is currently no widely accepted or unified taxonomy of criteria, resulting in some important criteria being omitted. Third, most evaluations of Web3 platforms fail to adequately account for practical, developer-focused issues including usability of developer tools, availability of libraries and SDKs, quality of documentation, community support, and governance models of the platform. These criteria are essential to the success of Web3 developers and have typically been given less weight than protocol-level characteristics. It was not until relatively recent times that some researchers began to give greater emphasis to such criteria and demonstrated the value of these criteria (e.g., “learning materials” and developer support were high-ranking in platform selection for a real project). Nevertheless, many academic studies of the comparison of Web3 platforms do not adequately assess the developer experience, the level of maturity of the ecosystem, and the governance structures of platforms that affect the feasibility and sustainability of developing applications on those platforms.

2.5. Contribution of this Study

This study fills those mentioned gaps in its own right. It establishes an integrated assessment model using fuzzy AHP and TOPSIS for the evaluation of blockchain platforms for the development of Web3 applications; thus, it combines the advantages of fuzzy AHP (evaluation of the ambiguity of judgments related to the weights of the criteria) with the advantages of TOPSIS (a clear ranking of platform alternatives). Additionally, the criteria used in this research were developed based on a thorough literature review and a suggested taxonomy (see Figure 1 of this research), thereby ensuring that both the technical aspects (performance, security, scalability) and the non-technical aspects (developer usability, tools, community, governance) of blockchain platforms are evaluated and given systematic weight. Our research uses a broader, and therefore more holistic and developer-focused assessment framework compared to previous studies that were limited to specific and/or ad-hoc criteria. Moreover, by evaluating additional criteria such as development tool support, documentation quality, upgrade governance, and ecosystem maturity — all of which have been inadequately evaluated or have received inadequate treatment in past research — our research provides a significant contribution toward a developer-centric evaluation of blockchain platforms. Overall, we believe that our proposed fuzzy AHP-TOPSIS method and the structure and breadth of the criteria set provide a unique and valuable lens through which to compare blockchain platforms. Thus, we can generate a detailed and multi-faceted ranking of platforms suitable for developing web applications, and therefore advance the state of the art and guide both researchers and practitioners when selecting appropriate blockchain platforms for their needs.

3. Research Methodology

This study's purpose is to create a support model that will assist with deciding which is the best blockchain platform to use to build Web3 web applications. To accomplish these objectives the methodology outlined below utilizes both fuzzy AHP [28] and fuzzy TOPSIS [29]. (i) These methodologies will assist in determining how important are the evaluation criteria when developing Web3 web applications and (ii) the best ranked blockchain platforms to utilize when developing Web3 web applications. Figure 2 outlines the three key steps of the study.

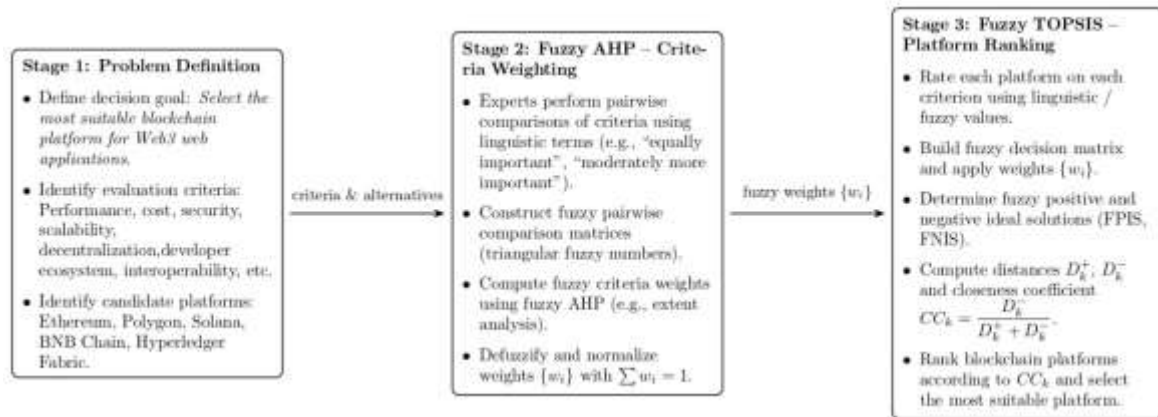


Fig 2. Conceptual framework integrating fuzzy AHP and fuzzy TOPSIS for blockchain platform selection

1. Step 1 - Problem Definition: Define the decision goal, define the evaluation criteria, and identify the candidate blockchain platforms.
2. Step 2 - Fuzzy AHP: Derive the fuzzy and defuzzified weights for each criterion through fuzzy pairwise comparisons from experts.
3. Step 3 - Fuzzy TOPSIS: Evaluate the closeness of the blockchain platforms to the ideal solution utilizing the criteria weights and fuzzy performance ratings.

Below are the details regarding the methodologies utilized in this study.

3.1. Evaluation Criteria and Alternatives

On the basis of the literature survey and the attributes of Web3 web applications, this study assesses the appropriateness of blockchain platforms using eight different criteria. The criteria are either of a cost-type (lower is better), or of a benefit-type (the higher the score, the better).

Table 2. Evaluation criteria for blockchain platform selection

Code	Criterion	Type	Brief description
C1	Transaction throughput	Benefit	Maximum sustainable transactions per second (TPS) relevant to targeted web application workloads.
C2	Latency / confirmation time	Cost	Average time to achieve transaction confirmation/finality.
C3	Transaction cost	Cost	Typical fee per transaction or smart contract execution from the end-user perspective.
C4	Security and network robustness	Benefit	Strength of consensus, attack resistance, and operational reliability (e.g. outage history).
C5	Scalability potential	Benefit	Ability to maintain performance under growing load (on-chain scaling, Layer-2 support, sharding).
C6	Smart contract capabilities	Benefit	Expressiveness, language support, runtime maturity, and quality of development tools/SDKs.

C7	Ecosystem maturity and support	Benefit	Size and activity of developer community, documentation, third-party tools, and ecosystem services.
C8	Decentralization and governance	Benefit	Degree of validator/node distribution, openness of participation, and transparency of governance.

Criteria C1-C5 address the technical aspects of each alternative, while criteria C6-C8 address governance and ecosystems aspects in relation to each alternative. These two types of criteria are essential for developing Web3 applications that are sustainable over time.

The set of alternatives to be compared includes five well-known blockchain platforms that have been developed based on differing philosophies regarding the architecture of blockchain platforms:

- A1 - Ethereum
- A2 - Polygon (a PoS blockchain platform)
- A3 - Solana
- A4 - BNB Chain
- A5 - Hyperledger Fabric

Ethereum, Polygon, Solana, and BNB Chain are four of the most popular permissionless, open platforms available today that are being utilized for development of decentralized web applications, while Hyperledger Fabric is one of the most prominent permissioned, consortium-based blockchain platforms available today. By comparing these five platforms, we will be able to determine how trade-offs between performance, openness, and enterprise control can be made in designing Web3 applications.

3.2. Data Collection and Expert Judgments

Expert opinions are used to judge both:

- a) The relative weights assigned to the criteria (in the fuzzy AHP methodology); and
- b) Each platform's level of performance on each criterion (in the fuzzy TOPSIS methodology); when there are limited, incomplete, or context-specific hard quantitative data.

Experts are selected from an expert panel consisting of experienced professionals in the areas of blockchain and Web3 (e.g., blockchain architects, senior smart contract developers and researchers). Experts are given:

- a) A structured questionnaire to assist in making pairwise comparisons between criteria based on linguistic terms; and
- b) A rating form to make assessments of how well each platform performed on each criterion, utilizing linguistic performance levels (i.e., "low", "medium" and "high").

You would replace the above generic description by an accurate and detailed description of the real composition of your panel (the number of experts in the panel, their years of experience, their roles, etc.), as well as an accurate description of your method of collecting data (survey online, workshop, Delphi rounds, etc.).

3.3. Linguistic Scales and Fuzzy Representation

Both the expert judgments made during the comparison of pairs of criteria, and the expert judgments made about the performance of each platform on each criterion, use linguistic

variables that are represented as triangular fuzzy numbers (TFNs). A generic triangular fuzzy number $\tilde{a}$ is defined as follows:

$$\tilde{a} = (l, m, u), \quad l \leq m \leq u \quad (1)$$

where l , m and u represent the lower limit of the expert's opinion, the most probable value of the expert's opinion, and the upper limit of the expert's opinion, respectively.

3.3.1. Fuzzy scale for pairwise comparisons (fuzzy AHP)

A 1-9 Saaty-like linguistic scale is used and converted to TFNs, for the pairwise comparison of criteria, for instance:

The reciprocal of comparison $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is given by:

$$\tilde{a}_{ji} = \left(\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}} \right) \quad (2)$$

Table 3. Example fuzzy scale for pairwise comparisons

Linguistic term	TFN ((l, m, u))
Equally important	(1, 1, 1)
Slightly more important	(1, 3, 5)
Moderately more important	(3, 5, 7)
Strongly more important	(5, 7, 9)
Extremely more important	(7, 9, 9)

3.3.2. Fuzzy scale for performance ratings (fuzzy TOPSIS)

Utilizing the linguistic terms mapped to TFNs, the platform performance on each criteria is also rate for instance,

- Very Low: (0, 0, 0.25)
- Low: (0, 0.25, 0.5)
- Medium: (0.25, 0.5, 0.75)
- High: (0.5, 0.75, 1.0)
- Very High: (0.75, 1.0, 1.0)

3.4. Fuzzy AHP for Criteria Weighting

The fuzzy AHP procedure for this research includes the following steps:

Step 1: Determine fuzzy pairwise comparison matrices for each expert

For each expert k , a fuzzy pairwise comparison matrix $\tilde{A}^k = [\tilde{a}_{ij}^k]$ of size $n \times n$ (where n represents the number of criteria) is constructed as follows. Each entry $\tilde{a}_{ij}^k$ represents the TFN provided by expert k to describe their assessment of the relative importance of criteria C_i compared to C_j .

Step 2: Combine the expert's opinions

There are various methods available for combining multiple expert opinions, for example, aggregating the TFNs for each pair (i, j) of criteria with respect to all the experts involved in the decision-making process.

$$\tilde{a}_{ij}^{\text{agg}} = \left(\min_k l_{ij}^k, \frac{1}{K} \sum_{k=1}^K m_{ij}^k, \max_k u_{ij}^k \right) \quad (3)$$

Step 3: Determine fuzzy criteria weights

By utilizing an existing fuzzy AHP methodology (such as Chang's Extent Analysis or a different methodology), the fuzzy synthetic extent $\tilde{S}_i$ for each criterion C_i is determined by aggregating fuzzy comparison matrices. Next, the fuzzy weight vector is calculated from the degrees of possibility between synthetic extents:

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n) \quad (4)$$

Where each $\tilde{w}_i$ is a TFN represents the relative importance of each criterion C_i .

Step 4: Normalization and Defuzzification

Each fuzzy weight $\tilde{w}_i = (l_i, m_i, u_i)$ is defuzzified to obtain the mean of the TFN:

$$w'_i = \frac{l_i + m_i + u_i}{3} \quad (5)$$

The resulting crisp weights are then normalized to ensure $\sum_{i=1}^n w_i = 1$:

$$w_i = \frac{w'_i}{\sum_{j=1}^n w'_j} \quad (6)$$

and the normalized vector $W = (w_1, w_2, \dots, w_n)$ represents the final importance weights of the evaluation criteria and is utilized during the fuzzy TOPSIS phase.

3.5. Fuzzy TOPSIS for Platform Ranking

Using the criteria weights developed through fuzzy AHP, fuzzy TOPSIS will be applied to rank five blockchain platforms.

Step 1: Develop fuzzy decision matrix

Let $\tilde{x}_{ij}$ represent the fuzzy ratings of alternative A_i (blockchain platform) with respect to criterion C_j . The fuzzy decision matrix is:

$$\tilde{X} = [\tilde{x}_{ij}], \quad i = 1, \dots, m, j = 1, \dots, n \quad (7)$$

with $m = 5$ and $n = 8$ in this study.

Step 2: Normalize the fuzzy decision matrix

For benefit criteria, normalization can use:

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*} \right), \quad u_j^* = \max_i u_{ij} \quad (8)$$

For cost criteria, a typical normalization is:

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}} \right), \quad l_j^- = \min_i l_{ij} \quad (9)$$

Step 3: Compute weighted normalized fuzzy matrix

The normalized ratings are weighted by the crisp criteria weights W_j :

$$\widetilde{v}_{ij} = \widetilde{r}_{ij} \otimes w_j \quad (10)$$

where $\otimes$ denotes scalar multiplication of a TFN by a positive scalar.

Step 4: Establish Fuzzy Ideal Solution & Anti-Ideal Solution

For each criterion C_j ; the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) are established as:

$$A^+ = \{\widetilde{v}_j^+ \mid \widetilde{v}_j^+ = (\max_i u_{ij})\}, \quad A^- = \{\widetilde{v}_j^- \mid \widetilde{v}_j^- = (\min_i l_{ij})\} \quad (11)$$

Step 5: Calculate Distance Measures & Closeness Coefficients

The distance between two TFNs $\widetilde{a} = (l_a, m_a, u_a)$ and $\widetilde{b} = (l_b, m_b, u_b)$ can be evaluated by:

$$d(\widetilde{a}, \widetilde{b}) = \sqrt{\frac{1}{3}[(l_a - l_b)^2 + (m_a - m_b)^2 + (u_a - u_b)^2]} \quad (12)$$

Calculate the distance between each alternative A_i and FPIS & FNIS:

$$D_i^+ = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^+), \quad D_i^- = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^-) \quad (13)$$

Establish a closeness coefficient value for alternative A_i :

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}, \quad 0 \leq CC_i \leq 1 \quad (14)$$

Step 6: Rank Blockchain Platforms

Rank alternatives from most desirable to least desirable based on CC_i . Alternatives that have a larger CC_i are closer to the ideal solution and therefore better suited to the decision-making criteria and the opinions of the experts. Alternatives with the largest closeness coefficient will be considered the best options to use as a blockchain platform for Web3 web applications for the stated decision context.

4. Results and Analysis

4.1. Fuzzy AHP Criteria Weights

The fuzzy pairwise comparison matrix used to evaluate the relative weights of the four criteria: Technical (C1), Economic (C2), Ecosystem & Usability (C3), and Governance (C4) is shown in table 4. The fuzzy pairwise comparison matrix has been constructed using a fuzzy pairwise comparison method. Table 4 provides an overview of the fuzzy pairwise comparison matrix with the fuzzy ratios derived by aggregating the input from the experts. As an example, Technical was compared to economic and it was determined that Technical was moderate to strong compared to Economic (fuzzy ratio $\widetilde{a}_{12} = (2,3,4)$) because the cost of the solution should be less important than the performance and security of the solution. It was also determined that Technical was slightly more important than Ecosystem (1,2,3) indicating that both C1 and C3 are nearly equal in importance. In addition, Technical was found to be significantly more important than Governance (3,4,5) which indicates that technical aspects of a solution will outweigh all other aspects in this

context. Reciprocal fuzzy pair-wise comparisons are made in the same way as their non-fuzzy counterparts (i.e., $\widetilde{a}_{21} = (\frac{1}{4}, \frac{1}{3}, \frac{1}{2})$ is the reciprocal of $\widetilde{a}_{12}$). All diagonal elements are set at (1,1,1). No violations of fuzzy preference logic consistency were identified within the fuzzy pairwise comparison matrix (Table 4).

Table 4. Fuzzy pairwise comparison matrix for criteria (TFN)

Criteria	C1: Technical	C2: Economic	C3: Ecosystem	C4: Governance
C1: Technical	(1, 1, 1)	(2, 3, 4)	(1, 2, 3)	(3, 4, 5)
C2: Economic	(1/4, 1/3, 1/2)	(1, 1, 1)	(1/3, 1/2, 1)	(1, 2, 3)
C3: Ecosystem	(1/3, 1/2, 1)	(1, 2, 3)	(1, 1, 1)	(1, 2, 3)
C4: Governance	(1/5, 1/4, 1/3)	(1/3, 1/2, 1)	(1/3, 1/2, 1)	(1, 1, 1)

Using the fuzzy AHP input, fuzzy weights of the other criteria were determined using standard fuzzy AHP methods (averaging judgments and normalizing). Fuzzy weights (triangular) and defuzzified values (centroid) of the criteria are shown in Table 5. With an approximate value of 0.475, Technical is the top weighted criteria; therefore, technical aspects (i.e., performance, scalability, etc.) of platforms have the greatest influence over platform choice. Ecosystem & Usability has the second-highest weighted criteria (0.255); followed by Economic (0.163); and finally, the lowest weighted criteria is Governance (0.107). The relative importance of the four criteria is also visualized in Figure 3, which shows the dominance of Technical and Ecosystem & Usability dimensions. These rankings are consistent with typical considerations for web application development where developers place a high priority on performance and reliability, and both community support and usability are very important to them. While cost considerations and governance structures are important, they are typically less important than the first three criteria. Also, it is interesting to note that the primary Technical and Ecosystem criteria are similar to the focus on decentralized platforms, security and developer resources which are necessary to achieve success of a blockchain platform.

Table 5. Criteria weights derived from fuzzy AHP

Criterion	Fuzzy weight (l, m, u)	Defuzzified weight
Technical (C1)	(0.245, 0.475, 0.857)	0.475 (47.5%)
Economic (C2)	(0.084, 0.163, 0.341)	0.163 (16.3%)
Ecosystem & Usability (C3)	(0.119, 0.255, 0.533)	0.255 (25.5%)
Governance (C4)	(0.061, 0.107, 0.234)	0.108 (10.7%)

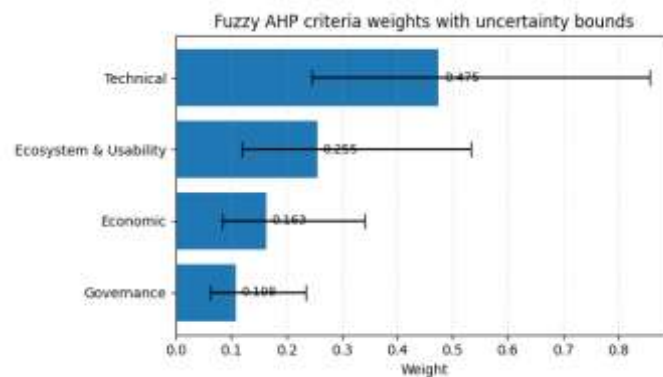


Fig 3. Defuzzified criteria weights obtained from fuzzy AHP.

4.2. Fuzzy TOPSIS Evaluation of Platforms

After obtaining the weights for the evaluation criteria, we evaluated the five Blockchain Platforms; i.e., Ethereum, Hyperledger Fabric, Solana, BNB Chain, and Polygon using an Integrated Fuzzy TOPSIS approach. Table 6 illustrates the fuzzy performance ratings of each Platform, based on each criterion (the fuzzy decision matrix). The ratings were derived from the opinions of experts who used linguistic terms (i.e., Very Low, Low, Medium, High, Very High) that correspond to triangular fuzzy numbers. Thus, in regards to Technical (C1), Solana was rated Very High (8, 9, 10) as it has shown the ability to process many transactions per second. BNB Chain had a Medium (4, 5, 6) rating technically since it has less decentralized features than Solana and is often times subject to performance trade-offs. Ethereum's technical abilities were rated High (7, 8, 9) as it has solid security, however its scalability is limited. Under Economic (C2), Ethereum earned a Low (1, 2, 3) rating due to its gas costs (transaction fees) that have been quite high over time, hindering the adoption of DApps. Polygon and Solana, on the other hand, both received Very High (8, 9, 10) economic ratings because of their low fees and efficient scalability capabilities. Ratings for Ecosystem & Usability (C3) reflect the level of developer support and community engagement; Ethereum earned a Very High (8, 9, 10) rating because of its large community of developers and its maturity. Hyperledger Fabric was rated Medium (4, 5, 6) because its use cases are typically found within enterprises. Governance (C4) ratings represent the degree to which the Platforms are decentralized and well-governed; Ethereum again received a Very High (8, 9, 10) rating for its robust governance structure, based upon community input, and its level of decentralization. On the other hand, BNB Chain was rated Very Low (0, 1, 2) on governance, due to the fact that a small number of validators (essentially managed by Binance) control the network. These fuzzy performance ratings provide a multi-faceted, realistic comparison of the Platforms under uncertainty. To provide a compact visual comparison, Figure 4 depicts the normalized criterion scores in heatmap form.

Table 6. Fuzzy performance ratings of blockchain platforms under each criterion

Platform	Technical (C1)	Economic (C2)	Ecosystem (C3)	Governance (C4)
Ethereum	(7, 8, 9) – High	(1, 2, 3) – Low	(8, 9, 10) – Very High	(8, 9, 10) – Very High
Hyperledger Fabric	(7, 8, 9) – High	(7, 8, 9) – High	(4, 5, 6) – Medium	(1, 2, 3) – Low
Solana	(8, 9, 10) – Very High	(8, 9, 10) – Very High	(4, 5, 6) – Medium	(4, 5, 6) – Medium

BNB Chain	(4, 5, 6) – Medium	(7, 8, 9) – High	(7, 8, 9) – High	(0, 1, 2) – Very Low
Polygon	(7, 8, 9) – High	(8, 9, 10) – Very High	(7, 8, 9) – High	(4, 5, 6) – Medium

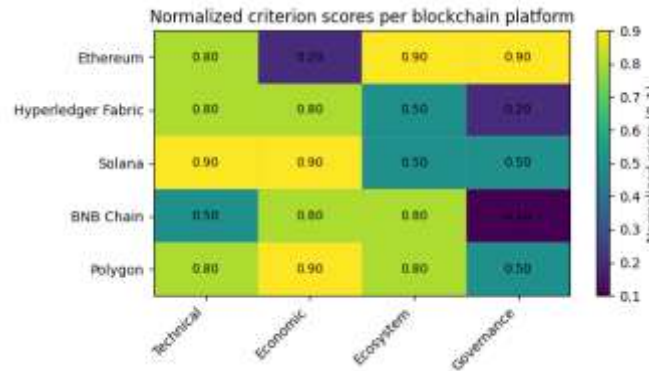


Fig 4. Heatmap of normalized criterion scores for the five blockchain platforms

TFN represent (low, likely, high) performance. For instance, Polygon's Economic rating (8, 9, 10) signifies that many of the experts involved in the assessment have rated the cost efficiency of Polygon extremely high (nearly "10") while they have assessed the cost performance of Ethereum as very poor (1, 2, 3). In addition, Hyperledger Fabric has high technical performance within a permissioned environment and is also very inexpensive (therefore High technical and economic scores) yet has fewer developers contributing to the Hyperledger Fabric public ecosystem and is governed centrally (therefore Medium ecosystem, Low governance). These more nuanced assessments are used as input to the TOPSIS calculation.

Within the TOPSIS methodology the fuzzy decision matrix was first normalized (because all of the criteria are benefit-type we normalized by the largest value for each criterion). Next, each element in the matrix was multiplied by the respective defuzzified weights listed in Table 5 to create the weighted fuzzy decision matrix. We then identified the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) for each of the criteria. The FPIS is the composite alternative with the best performance in each criterion, created by identifying the highest fuzzy rating among the platforms for that criterion (i.e., $\bar{A}^+ = \{max_i \quad \bar{v}_{ij} \mid j = 1, \dots, 4\}$). Similarly, the FNIS is the collection of worst performance fuzzy ratings for each criterion (i.e., $\bar{A}^- = \{min_i \quad \bar{v}_{ij} \mid j = 1, \dots, 4\}$). In this case, the FPIS fuzzy ratings were approximately (following weighting) Very High in all criteria (due to at least one platform being ranked very high in each of the criteria), and the FNIS were rated Very Low (reflecting largely the extreme ratings of Ethereum's cost and BNB's governance).

Utilizing the weighted ratings, we calculated the distance of each platform from both the ideal and negative-ideal solutions. The vertex distance method was employed to compute the distance d_i^+ of each platform i to the FPIS, and d_i^- of each platform i to the FNIS. Essentially, we computed for each platform the degree to which its fuzzy performance vector deviates from the "optimal" platform and from the "poor" platform in the multi-criteria space. The distance $d(\tilde{p}, \tilde{q})$ of two triangular fuzzy numbers $\tilde{p} = (p_l, p_m, p_u)$ and $\tilde{q} = (q_l, q_m, q_u)$ can be computed using the vertex method:

$$d(\tilde{p}, \tilde{q}) = \sqrt{\frac{(p_l - q_l)^2 + (p_m - q_m)^2 + (p_u - q_u)^2}{3}} \quad (15)$$

After computing the distances d_i^+ and d_i^- for each platform i , the closeness coefficient was calculated as

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (16)$$

where a larger C_i indicates that alternative i is closer to the ideal. Table 7 provides the resulting distances and closeness coefficients for the five evaluated platforms, and the resultant ranking.

Table 7. Distances to ideal solutions and closeness coefficients of the platforms

Platform	d_i^+ (Distance from FPIS)	d_i^- (Distance from FNIS)	Closeness C_i	Rank
Polygon	0.365	1.026	0.738	1 (Best)
Solana	0.543	0.947	0.635	2
Ethereum	0.782	1.074	0.579	3
Hyperledger Fabric	0.983	1.066	0.521	4
BNB Chain	1.156	0.854	0.425	5 (Worst)

The closeness coefficients (the last column in Table 7) show the final performance score of each platform relative to the ideal. A higher C_i shows that the platform is closer to the "optimal" balanced platform when considering all criteria simultaneously. Thus, Polygon had the highest C_i of 0.738 and is ranked as the top-rated platform in this evaluation. This indicates that Polygon is the most similar to the "ideal" when considering all criteria simultaneously. Solana ranks second best with $C_i \approx 0.635$, followed by Ethereum with $C_i \approx 0.579$. Hyperledger Fabric (with a C_i of 0.521) and BNB Chain (with a C_i of 0.425) rank fourth and fifth, respectively. An illustration of the closeness scores of the evaluated platforms is provided in Figure 5.

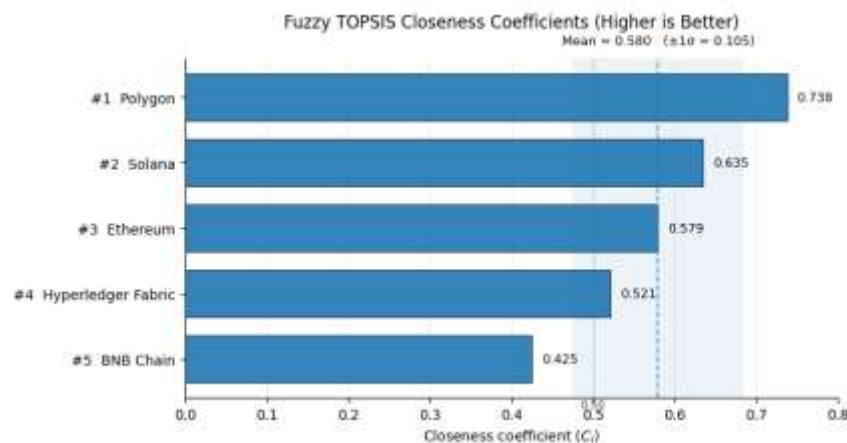


Fig 5. Fuzzy TOPSIS closeness coefficients

5. Discussion

The final rankings provide some important information regarding the strengths and weakness of each of the blockchain platforms for web application development. These trade-offs are summarized in the radar chart in Figure 6, which contrasts the normalized criterion scores of the top three platforms. It appears that Polygon (Rank 1) is the most appropriate platform based upon the results of this research. This is due to the fact that Polygon performed well in both the Economic and Ecosystem categories while achieving good results in the Technical areas. As a layer-two Ethereum solution, Polygon offers an economic advantage through very low transaction fees and high throughput. Additionally, because many Ethereum developers and tools can be easily ported onto Polygon's compatible platform, the Polygon ecosystem is able to leverage the vast number of developers and tools available for Ethereum use, resulting in a large user community and usability benefit. While Polygon's governance was ranked as only "moderate" because of the relative lack of decentralization compared to Ethereum, this moderate rank in governance did not diminish the advantages provided by Polygon's superior performances in other areas. Overall, Polygon offers a good balance between scalability and cost-effectiveness without compromising too much on decentralization; therefore, Polygon's closeness score to the ideal was the largest.

Polygon (Rank 1) is followed closely by Solana (Rank 2). Solana performed particularly well in Technical and Economic categories. Experts ranked Solana as one of the best in terms of throughput and transaction cost (it is known for high transactions per second and minimal fees). These advantages were reflected in the high value of d_i^- (the minimum distance to the worst-case) and the relatively small value of d_i^+ (maximum distance to the ideal) for Solana. Solana's lower ranking than Polygon can be attributed to the lower values for Solana in the Ecosystem and Governance categories. Solana has a developing, albeit smaller, developer and community support ecosystem compared to Ethereum/Polygon, which negatively affected Solana's usability score. Furthermore, Solana's network, while highly decentralized, has experienced several outages and criticisms of having a somewhat more centralized validator set than Ethereum (and thus affecting Solana's governance score). These factors created a greater distance to the ideal for Solana in these categories, thus decreasing Solana's closeness coefficient in comparison to Polygon. However, Solana's overall high score demonstrates that it is a viable option for web application development if raw performance and low costs are of primary importance.

Ethereum (Rank 3) is located in the middle. Of particular note, Ethereum received the highest ratings in two categories (Ecosystem and Governance) and the lowest rating in another (Economic). The mixed results from the fuzzy TOPSIS analysis are clearly demonstrated in the closeness coefficient of 0.579 for Ethereum. Ethereum has a large, rich developer ecosystem, tooling and long-standing community support -- evidenced by over 2,100 full-time developers and numerous applications -- and this greatly helped to elevate Ethereum's Ecosystem & Usability score to the maximum possible. Additionally, Ethereum's dedication to decentralization and community-based governance was another differentiating factor in the study, demonstrated by the highest Governance rating of the four options. These characteristics drew Ethereum closer to the ideal for those categories. Nevertheless, high transaction costs and scalability problems caused a significant drop in Ethereum's Economic score. The fuzzy TOPSIS results demonstrate the trade-off in the quantitative results: Ethereum had the greatest distance from the ideal in the economic criteria, i.e., it was the worst in this category (its fuzzy cost rating was (1,2,3)). Therefore, this negative impact greatly reduced Ethereum's total closeness. If the cost of using a blockchain is the primary concern, then Ethereum's ranking will suffer, however, the proven dependability of Ethereum, along with its broad developer support ecosystem, keeps it competitive in the market.

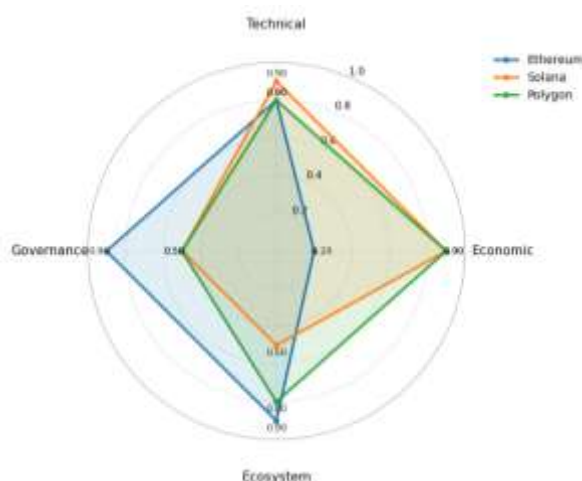


Fig 6. Radar chart of normalized criterion scores for the top three platforms

The closeness of Hyperledger Fabric (Rank 4) is .521. Fabric's results show how "the best" platform can vary depending on the use case. Our weighted analysis included many publicly facing criteria such as Ecosystem and Governance; therefore, these were heavily weighted over Fabric. Hyperledger Fabric is a permissioned blockchain used primarily in enterprise environments, therefore, Hyperledger Fabric does not have a large open developer community nor does it have permissionless governance. These factors contributed to Hyperledger Fabric being ranked Low in Ecosystem (Medium) and Low in Governance (Low). On the other hand, Fabric excels at the Technical and Economic factors: Fabric offers high throughput and low transaction costs (there are no cryptocurrency transaction fees); this aligns with prior studies that state Fabric's throughput is superior to other platforms in permissioned blockchain environments. Although Fabric excelled at the Technical factor, the fuzzy AHP weightings of this study provided higher weight to technical and ecosystem aspects, thus although Fabric's technical superiority was able to surpass its relatively weak ecosystem, the overall ranking was not improved by this. Therefore, if the decision context were enterprise internal applications and the decision makers placed a heavy weight on cost or throughput while providing less weight to public ecosystem, Fabric's overall ranking could potentially increase. As of now, Fabric has a high performance, low cost, yet limited openness that yielded an average ranking overall.

BNB Chain (Rank 5) was the least ranked platform per our analysis. The closeness coefficient of BNB Chain (.425) was substantially less than the other platforms, which indicates a sizeable difference between BNB Chain and the ideal solution. BNB Chain, formerly known as Binance Smart Chain, showed areas of strength – BNB Chain received ratings of High in both Economic and Ecosystem criteria. This indicates that BNB Chain provides low transaction fees and an EVM-compatible environment that has drawn many DApp developers (particularly those that migrated from Ethereum to take advantage of lower gas fees). Nevertheless, BNB Chain's weakness in Technical and Governance criteria outweighed the strengths. From a technical perspective, BNB Chain is less decentralized and has exhibited scalability limitations (due to the trade-offs made in the design of BNB Chain, it has sacrificed some level of decentralization for throughput, with 21 active validators). We therefore rated BNB Chain only Medium in Technical performance due to this trade-off. Furthermore, BNB Chain's weakness in Governance was more critical – BNB Chain is frequently criticized for being overly centralized because the majority of validators are controlled by Binance, thus undermining trust and resilience. This resulted in BNB Chain receiving the lowest Governance rating of all alternatives. Since Governance is the lowest weighted criterion in the analysis, but still influences the result, BNB Chain's

extremely poor performance in this area increased its distance from the ideal solution. Also, BNB Chain's medium technical rating (which was acceptable) could not compete with the Very High technical ratings of Solana or the High technical ratings of Ethereum/Polygon. Therefore, in essence, BNB Chain appears to be a cost-effective platform that nonetheless falls short when rigorous decentralization and/or top tier performance is required. The fact that BNB Chain is ranked last in this analysis, further supports the notion that the deficiencies in decentralization and lower performance rates than Solana/Ethereum/Polygon outweigh the benefits of BNB's low fees.

Our integrated fuzzy AHP-TOPSIS evaluation indicates that Polygon is the most well-rounded option for web applications; Solana is second and Ethereum follows close behind due to different strengths in their respective areas. The reasons that Polygon ranked highest were based upon the technical merits of being scalable at a low cost and having matured ecosystems and overcoming many of the traditional downsides associated with using Ethereum. Solana has the fastest performance at the lowest cost and is a good fit for apps that require high throughput. However, Solana's performance comes at a price — fewer users will likely find the Solana ecosystem appealing compared to other options. Although Ethereum has the largest community and is one of the most secure blockchain platforms available today, it is still a general-purpose platform that does not have to concern itself with cost; however, the large community and level of security make Ethereum a viable option for projects that value either of these aspects above all else. Hyperledger Fabric is highly effective within private/consortium environments that place a premium on performance and granular control. However, the lower ranking assigned to Hyperledger Fabric within this comparison is reflective of its lower suitability for open-source web applications that benefit from widespread ecosystem support. Lastly, although BNB Chain is popular in several areas of DeFi and gaming, it was ranked last under the weighted criteria we selected because of governance and decentralization issues which outweighed its low-cost advantages. These results offer practical guidance to developers and decision makers. If you are looking to create a web application with the greatest reach among potential users and developer support, then choosing between Polygon and Ethereum should be your first step, given both have high ecosystem scores and technically robust foundations. If your use case requires you to maximize throughput while reducing costs, and you're willing to sacrifice some degree of decentralization, then Solana may be your best option. On the other hand, if you desire to create a permissioned environment that values control and enterprise grade performance above decentralized access, then Hyperledger Fabric could potentially be the right solution for you — just keep in mind our analysis placed a penalty against it for factors that are irrelevant when creating a closed system. The method used for this study, fuzzy AHP for assigning criteria weights and fuzzy TOPSIS for ranking, enabled us to quantitatively evaluate these trade-offs under conditions of uncertainty and created a transparent framework that allows stakeholders to modify the criteria weights (for instance, increasing the weight of Economic if cost is even more important) and run the analysis again to see what changes occur in the rankings. Ultimately, there is no single "best" blockchain platform; the best platform will depend on the unique priorities of each project. However, the results of our evaluation identify Polygon as a particularly attractive all-around option for web applications based on a balanced consideration of technical, economic, ecosystem, and governance factors. Additionally, our results are consistent with recent trends in the blockchain industry, specifically that multi-chain solutions (such as Polygon) and layer two solutions (also such as Polygon) are becoming increasingly popular as they combine the high performance needed by many applications with the security and community of Ethereum. Therefore, this integrated evaluation provides not only rankings of platforms,

but also explains why Platform X was ranked above Platform Y, providing insights into the critical decision factors for blockchain adoption in web development.

6. Sensitivity Analysis and Robustness

6.1. Design of Weighting Scenarios

While the results of MCDM procedures depend upon the respective weights given to the criteria, it is important to determine if the ranking of blockchain platforms will remain consistent even if the decision maker's weights vary reasonably. In this study, the weights for the base case criteria were determined through fuzzy AHP, which resulted in the following weight vector:

$$W^{(0)} = (w_{\text{Tech}}, w_{\text{Econ}}, w_{\text{EcoSys}}, w_{\text{Gov}}) = (0.475, 0.163, 0.255, 0.108) \quad (17)$$

To determine if the ranking of the blockchain platforms would be affected by different decision makers' preferences, four additional weighting cases were identified to reflect differing, yet realistic, decision maker preference profiles:

- S0 – Baseline (fuzzy AHP weights):
 $W^{(0)} = (0.475, 0.163, 0.255, 0.108)$
- S1 – Economic-emphasis (cost-oriented):
 Higher importance on Economic, while Technical remains important and Ecosystem/Governance are slightly down-weighted:
 $W^{(1)} = (0.30, 0.35, 0.20, 0.15)$
- S2 – Technical-emphasis (performance-dominant):
 Technical is dominant; Economic and Governance are modest, Ecosystem moderate:
 $W^{(2)} = (0.60, 0.10, 0.20, 0.10)$
- S3 – Ecosystem-emphasis (developer-centric):
 Ecosystem & Usability receives the highest weight, with Technical still important and Economic/Governance slightly lower:
 $W^{(3)} = (0.30, 0.15, 0.40, 0.15)$
- S4 – Governance-emphasis (decentralization-centric):
 Governance weight is strongly increased to reflect contexts where decentralization and governance structure are prioritised:
 $W^{(4)} = (0.30, 0.15, 0.20, 0.35)$

The sums of the weights for all four scenarios equal 1. Collectively, S0–S4 provide a realistic representation of decision makers' potential preferences from a cost-focused enterprise decision-making (S1) perspective to performance (S2), developer experience (S3) and governance (S4) perspectives.

6.2. Scenario-Based Ranking Results

A fuzzy TOPSIS method was applied to evaluate the performance for each scenario $W^{(s)}$ based upon the same fuzzy performance ratings provided in Table 6, but with the weights being adjusted to accommodate the new scenarios. As a result, for each scenario, a set of closeness coefficients $CC_i^{(s)}$ were generated and a resultant ranking of the platforms was developed. Due to the nature of the problem, rather than present the full range of closeness coefficients, the ranking of the alternative platforms from best to worst is presented in Table 8.

Table 8. Platform rankings under different weighting scenarios

Scenario	Weights (Tech, Econ, EcoSys, Gov)	Ranking (best → worst)
S0 – Baseline	(0.475, 0.163, 0.255, 0.108)	Polygon > Solana > Ethereum > Fabric > BNB
S1 – Economic-heavy	(0.30, 0.35, 0.20, 0.15)	Polygon > Solana > Fabric > Ethereum > BNB
S2 – Technical-heavy	(0.60, 0.10, 0.20, 0.10)	Solana > Polygon > Ethereum > Fabric > BNB
S3 – Ecosystem-heavy	(0.30, 0.15, 0.40, 0.15)	Polygon > Ethereum > Solana > BNB > Fabric
S4 – Governance-heavy	(0.30, 0.15, 0.20, 0.35)	Ethereum > Polygon > Solana > Fabric > BNB

Several trends are observed from the scenario evaluation:

- Polygon is ranked in the top two in all five scenarios, and is ranked first in three scenarios (S0, S1, S3).
- Solana's position varies among the scenarios, from first to third, depending on whether the decision maker places emphasis on the technical and economic criteria.
- Ethereum's ranking increases to second in the scenario with an ecosystem heavy focus (S3) and to first when governance is the most heavily weighted criterion (S4).
- Hyperledger Fabric's ranking increases when Economic is heavily weighted (S1), but decreases when the decision maker has an ecosystem or governance focus.
- BNB Chain remains at the bottom in all scenarios, and therefore does not appear to have structural advantages over the other platforms for the criteria examined.

6.3. Visual Sensitivity Analysis

To demonstrate the relative stability and shift in the rankings of the platforms across the scenarios, a graph (not shown) of the ranking of each platform as a function of the weighting scenario (S0–S4) is shown below.

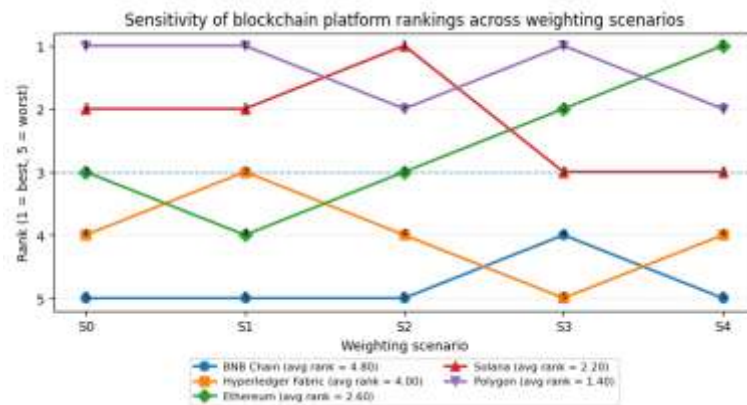


Fig 7. Sensitivity of blockchain platform rankings across weighting scenarios S0–S4.

Figure 7 presents the trend of the ranking of the platforms as a function of the weighting scenario (S0–S4) as described above. The vertical axis represents the ranking (best=first, worst=fifth), and the horizontal axis represents the weighting scenario. As indicated by this Figure, Polygon demonstrates significant stability in its ranking. Regardless of the scenario, Polygon is ranked no lower than second. Therefore, Polygon can be viewed as a robust choice regardless of the preference structure of the decision maker. Solana demonstrates significant variation in its rank across the scenarios. Solana is ranked first

in the technical-heavy scenario S2, in which raw performance and low transaction fees are most relevant, while it is ranked third in the ecosystem-heavy and governance-heavy scenarios (S3 and S4). Ethereum displays the reverse trend. Ethereum never achieves the number one rank in the baseline or performance-oriented weights, but its rank is improved significantly when the weights emphasize ecosystem quality or governance. In the governance-heavy scenario S4, Ethereum achieves the highest rank and reflects the superior decentralized and governance model of Ethereum. Hyperledger Fabric's rank is largely influenced by whether public-facing ecosystem and governance elements are given value. When public-facing ecosystem and governance elements are given a high degree of value, Hyperledger Fabric's rank declines (S3 and S4), whereas when an emphasis is placed on public-facing governance, Hyperledger Fabric's rank improves (S1). BNB Chain demonstrates the lowest rank in Figure 7 for each scenario since BNB Chain's strengths in cost and ecosystem are unable to offset the weaknesses in governance and technical decentralization for the other platforms when compared.

6.4. Robustness of the Decision

A large number of scenarios were evaluated using the sensitivity analyses. As such, the major results of this study have been found to be relatively insensitive to the different scenarios analyzed. In a variety of different possible preferences, polygon was the top choice in terms of overall attractiveness as an all-around web3 development platform. Solana and Ethereum represent a stable second tier of options. Solana represents a better option than ethereum from a performance-cost perspective, whereas Ethereum is generally preferred over Solana from an ecosystem-governance perspective. Hyperledger fabric is appropriate for use only in very specific enterprise-style trade-offs. In all scenarios analyzed, BNB Chain has consistently been the lowest ranked platform among those evaluated.

This is important from a decision-making support perspective for two reasons:

- Stability of the primary recommendation: The fact that polygon never falls below second in all of the scenarios examined, confirms that the primary recommendation to favor polygon (in balanced priority situations) is not a function of an arbitrary set of weights used to create the ranking.
- Transparency of preference-based movement between the first and second tiers: The model clearly exhibits intuitive behavior when extremely high preferences are applied (such as S2 or S4): solana is clearly favored when the primary focus is on performance, ethereum is clearly favored when the primary focus is on governance and decentralization. This behavior will help to increase confidence in the model as it provides evidence that the model's rankings are based upon qualitative information regarding the characteristics of each of the four platforms being studied.

The fuzzy AHP-TOPSIS methodology produces a ranking that supports what-if analysis of stakeholder priorities. Therefore, decision-makers can evaluate how changes in emphasis (for example, from cost to decentralization) would affect the recommendation made by the methodology. Additionally, the methodology provides evidence that in a large majority of cases where decisions are made based upon a balanced evaluation of multiple dimensions (Technical, Economic, Ecosystem and Governance) polygon will be the most robust choice.

7. Conclusion and Future Work

Fuzzy AHP and fuzzy TOPSIS decision support system has been developed to determine the appropriate blockchain platform for developing the Web3 applications. Fuzzy AHP has

determined the weightage of criteria based on subjective judgment and fuzzy TOPSIS evaluated and ranked the blockchain platforms. Four major categories (technical, economic, usability and governance) were assessed along with five major blockchain platforms; Ethereum, Hyperledger Fabric, Solana, BNB Chain, and Polygon.

Based on the fuzzy AHP results it was found that the technical criteria (Performance, Scalability, Security) and usability criteria (Developer Tools, Documentation, Community, Third-Party Services) have the greatest impact on the development of Web3 application. They are followed by economic criteria (transaction fees, on-chain storage, etc.) and then the governance (Decentralization Level, Permission Model, Upgrade Process). With the fuzzy TOPSIS results, the rankings were generated using the weights obtained through the fuzzy AHP. Based on the rankings, Polygon had the highest score overall and thus would be the best option for Web3 developers. It was ranked number one due to a good balance between technical capabilities, very low transaction fees and a well-developed ethereum compatible ecosystem. Solana was ranked high due to its extremely high throughput and low transaction fees. Although Ethereum has a strong governance model and ecosystem, its economic performance was relatively weak. Hyperledger Fabric scored high on both the economic and technical aspects of the criteria. However, Hyperledger Fabric was penalized for having an open ecosystem and governance model that is less favorable in a Web3 context. BNB Chain was the lowest scoring platform because of governance and decentralization issues outweighing the benefits of being low-cost and having a well-developed ecosystem.

An additional sensitivity analysis was performed to test the stability of the conclusions obtained. Different weighted profiles reflecting a variety of different preference profiles (i.e., cost-oriented, performance-oriented, ecosystem-oriented, governance-oriented) were tested. Regardless of the profile used, Polygon, Solana and Ethereum made up the top tier of platforms. Polygon was never lower than the second place platform in any of the sensitivity tests. Therefore, Polygon's position is stable. Solana rose to first place when the Technical and Economic criteria were weighted higher. Ethereum moved to the top spot when Governance and/or Ecosystem were weighted higher. Hyperledger Fabric was better positioned in cost-weighted scenarios. However, Hyperledger Fabric was not among the top three platforms in any of the other weighted scenarios. BNB Chain was the least preferred platform in every scenario. These results indicate that the proposed method is somewhat resistant to reasonable variations in the weighting of the decision maker's preferences and that the identified platforms match the qualitative properties of the corresponding technologies.

In practice, the proposed framework provides a structured and repeatable means of evaluating competing blockchain platforms for the purpose of selecting an optimal platform for the development of a Web3 application. Instead of making ad-hoc decisions or comparing competing platforms using a single metric, stakeholders can now use the proposed framework to articulate their preferences, express qualitative judgments using linguistic variables, and receive a quantitative and explainable ranking of potential platforms. Additionally, the explicit representation of uncertainty using fuzzy set theory is particularly beneficial given the rapid evolution of the blockchain technology space where the data may be incomplete and the expert opinions may be uncertain. Furthermore, the framework is modular such that criteria may be either added, removed, or modified and new platforms may be added without changing the underlying methodology. Therefore, the proposed framework is not limited to the specific blockchain

platforms that were evaluated in this study, but rather can be applied to any generation of blockchain-based architectures.

There are many constraints on this study that suggest the potential for future research. The first constraint on the study is that the empirical study used a very limited number of platforms and only a few expert opinions. If we include more platforms (for example, Layer-2, and application-specific chains), if we use a greater number of experts from a greater diversity of backgrounds, then the study will have greater validity. The second constraint on the study is that there is no one "right" way to construct a hierarchical structure of criteria (the study constructed a hierarchical structure based on what the authors believed were the most important characteristics). We can add additional characteristics to the hierarchy for applications that value those characteristics such as sustainable (i.e., energy consumption and carbon footprint), regulatory compliance, or interoperable with legacy systems. The third constraint is that the fuzzy AHP-TOPSIS model assumes that all the criteria are independent (i.e., the values assigned to each criterion do not affect the values assigned to other criteria). In practice, however, some criteria (for example, technical performance/cost, governance/security) may not be independent and may be best analyzed using network-based methods (for example, fuzzy ANP) or multi-stage models.

Therefore, the primary area of interest for future research is to extend and generalize the framework. One potential direction is to add dynamic/ time-dependent information to the model. Since the performance of a blockchain platform, its fee structures, and the ecosystem of users around the platform are constantly changing (especially since new scaling solutions and protocol upgrades are being continuously added), adding this type of dynamic information to the model will provide a better representation of how these platforms perform over time. An additional direction is to create an interactive decision support system that allows the user to change the weight of the criteria in real-time and view how changes in the criteria weights affect the ranking of the blockchain platforms. Finally, the study could compare different domains (for example, DeFi, gaming, supply chain, identity management) to determine how different domain specific requirements affect which blockchain platforms are considered the most attractive and to determine reusable preference profiles for different types of applications.

In summary, the fuzzy AHP-TOPSIS method described in this study is a valid, practical, and flexible method to make decisions about the selection of blockchain platforms for Web3 web applications. The method uses a structured hierarchy of criteria to evaluate the characteristics of each blockchain platform, uses fuzzy logic to handle the ambiguity associated with assigning numerical values to non-numerical criteria, and uses sensitivity analysis to identify which criteria have the greatest influence on the decision. Therefore, the method can both provide a specific recommendation (in this case, recommending Polygon and possibly Solana or Ethereum depending upon the criteria selected) and provide a general framework that can be applied to future platforms and future decision-making environments.

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