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FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP) USING GEOMETRIC MEAN METHOD TO SELECT BEST PROCESSING FRAMEWORK ADEQUATE TO BIG DATA

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ABSTRACT

Big data is considered a hotspot, as all organizations realize the importance of their big data to gain insights that help organizations develop and understand consumer requirements. Big data needs large storage capacity and strong processing frameworks in order to clean, process, and analyze it. Fortunately, cloud computing offers many services and processing frameworks that facilitate the storage and processing of big data. But the issue here is how to choose the best suited processing framework for big data of financial services. The best processing framework is chosen based on big data criteria and financial services requirements. We used MCDM methods to solve this decision problem and evaluated five big data processing frameworks (Spark, Hadoop, Flink, Storm, and Samza) based on twelve criteria. These criteria were collected from previous researches. Analytical hierarchy process (AHP) is a powerful and simple method of MCDM methods, but many of researchers believe that it has some weakness due to some uncertainty issues. Many researchers have preferred to combine fuzzy set theory with AHP to solve the uncertainty problem. This work introduces fuzzy AHP using geometric mean method in cloud service selection based-problem. The results show that Hadoop framework has the highest level of security, availability, scalability,and compatability, but has the heighest cost. Spark has the highest storage capacity , speed, and best processing mode at lower cost. Flink has the best usability, and processing. Storm has the best performance, sustainability, and is the cheapest. The validity of our results and the robustness of our hybird proposal were aproved by applying sensitivity analysis.

Key words: *Big Data, Cloud Computing, MCDM, Fuzzy Set Theory, AHP, Geometric Mean Method, Hadoop, Spark, Storm, Flink, and Samza.*

1. INTRODUCTION

"Data is gold", but the volume of data itself doesn't matter as much as companies can obtain from this data. Big data can be processed, cleaned and analyzed to gain insights that help make better business decisions and strategic business moves. Organizations use big data processing frameworks with high-powered analytics to drive projects, which help identify root causes of failures, issues and defects in near-real time, Generating coupons at the point of sale based on the customer's buying habits, Recalculating entire risk portfolios in minutes, Detecting fraudulent behavior before it affects your organization [1], [2]. But when the expression "Big Data" is used by vendors, may refer to an umbrella expression including data, data mining, data storage, data analysis, data sharing, data visualization, and Data processing frameworks along with tools and techniques used to process and analyze data. Big data has some characteristics which can be defined as follow:

- **Volume:** indicates huge 'volumes' of data that might be petabyte (1,024terabytes), Exabyte (1,024 Petabytes), or zettabytes [3].
- **Velocity:** refers to the speed at which data is being created in real-time [3].
- **Variety:** refers to structured, unstructured, and semi structured data in different formats such as emails, PDFs, photos,

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videos, audios, SM posts, and so much more[3].

- **Veracity:** refers to data quality, as completeness, validity, accuracy, consistency, availability and timeliness.
- **Value:** Value is the utility, meaning or profit that can be derived from the use of Big Data.
- **Variability:** refers to the collected data can be inconsistent. E.g. Trends in social media. The daily and seasonal peak data loads induced by events can be difficult to manage.
- **Complexity:** Data flows from different sources; this makes it difficult to link, consistent, clean and transforms data [4].

Cloud computing is a host of remote servers used to manage and process huge volumes of data and a network of computers to store data and run applications. The combination between big data and cloud computing signifies a scalable and cost-effective solution in big data processing and analytics [5]. The problem is when we are dealing with multiple vendors, multiple services and various preferences [6]. Cloud service selection based MCDM is a process of making a decision at which the best cloud service suitable for business requirements and through which we can achieve the largest possible profit and achieve a competitive advantage. The research issue is identifying the best processing framework adequate to big data of the financial services.

Case study: Financial services

This research focuses on big data of financial services, because of its vital importance to citizens when dealing with financial institutions such as banks. Financial institutions have sensitive transactions that depend on mutual trust and security precautions to their clients. The challenges that face these institutions evolves the need of an approach to make a decision on which the best processing framework adequate to their sensitive data to prevent violations and expose their data to theft and fraud [8].In financial services industry we should focus on privacy on data and security of large amounts of financial information for consumers. Therefore, a framework must be provided for regulating data privacy and security practices. Banks have enormous amounts of customer data (i.e. deposits/withdrawals at ATMs, purchases at point-of-sales, payments done online, customer profile data , but due to their silo, product-oriented organizations, they are not very good in utilizing these rich data sets. Luckily, cloud solutions provide a cost effective and flexible (i.e. elastic scalability) infrastructure (but also higher-level services) to support these Big Data processing frameworks [7].

Multi criteria decision making (**MCDM**)) is an important branch of operations research, and a powerful tool that helps decision makers in solving complicated decision problems which are based on conflicting criteria and requirements. It is worth nothing that the MCDM not only deals with criteria, alternatives, priorities, methods, theories, and techniques but also deals with different personnel views of decision makers. MCDM is the best tool to choose best, logical, and compatibility alternative through different and conflicting opinions of a group of decision makers [9], [10]. All MCDM methods depend on a decision matrix which consists of set of criteria and alternatives. MCDM methods used to assign weights to criteria (qualitative or quantitative). However, assigning weights to qualitative criteria can be affected by decision maker preference and can vary extremely from one decision maker to another. To cover this weakness Saaty [9] suggested a numerical scale (0-9) to transform qualitative data into quantitative [11]. Based on the literature review in context of cloud services selection, we can say that AHP is the most MCDM method used because of its powerfulness. Other methods used like ANP, TOPSIS, VIKOR, and others. Many researchers agreed that the Saaty's AHP method has some challenges. For example the uncertainty associated with the decision makers judgment of the importance of criteria, doesn't take into account that different preferences and personal judgment of decision maker have a significant influence on the AHP outcome. To overcome these problems, some researchers have preferred to integrate the Saaty's AHP with fuzzy set theory for uncertainty control [12]. For examples [29], [32] resolved uncertainties and ambiguity in human's decision through fuzzy set theory. The main goal of this thesis is to integrate the fuzzy set theory with AHP method and practically applying Fuzzy AHP in our big data based problem. The rest of this paper is organized as follows: Section 2 consists of literature review for the problem of selection of the best cloud services with MCDM methods. Section 3 presents the proposed methodology to help enterprises choose the best suitable cloud framework to achieve their goals. In section 4,

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we discussed results of the proposal. Section 5 validates results of the hybrid approach by using sensitivity analysis. Section 6 contains conclusion.

2. LITERATURE REVIEW

MCDM is concerned with solving decision problems which includes multiple criteria. There are many researches in such problems. In [13] Jabrane Kachaoui and Abdessamad Belangour focused on identifying criteria to select the most suitable platform according to the requirements of various big data, and then they applied AHP on different three use cases to analyze business challenges. In [14] Martin Lněnička proposed an AHP model for selecting the analytics platform for big data based on different requirements of three use cases, and discussed in details some of the big data analytics platforms. In [15] they developed a systematic review of literature on the real cases that applied AHP to evaluate how the criteria are being defined and measured. In the 33 cases selected, they mainly used literature to build the criteria and AHP or Fuzzy AHP to calculate their weight, while other techniques were used to evaluate alternatives. In [16], paper suggested a method for selecting key security assessment criteria based on cause-and-effect relationships between services, threats, vulnerabilities, and security controls, using multiple assessment factors including significance, likelihood, and impact. (ANP) is used to estimate the direct effect between features, and (DEMATEL) is used to obtain the overall effects (direct and indirect) between those features. In [17] paper, an optimized and redundant cloud selection model was presented based on the multi-criteria decision analysis under study. The weighted sum model, the fuzzy analytical hierarchy process, and the fuzzy revised analytical hierarchy process are evaluated on ten criteria. [18] Focus on evaluating cloud farm services that are PaaS (Platform-as-Services) cloud services that provide the entire platform for animators to view files using cloud resources. This work identifies the Quality of Services (QOS) features that are important for animators to choose cloud rendering farm services. In [19] a model based on the combination of weights and gray correlation analysis has been proposed. First, direct trust and recommendation together constitute trust and reputation overall, resulting in a more accurate public trust. Second, the approximate group theory and AHP based method for direct confidence are used. In [20], the researcher proposed an approach based on the AHP method, which manages the selection of the appropriate cloud service for big data based on its standards and criteria. The case in question relates to selecting an appropriate big data cloud service in the context of the National Health Service (NHS) of the United Kingdom (UK). In [21] Researchers used Fuzzy AHP to analyze parameter weights for factors related to 3D printer selection. In particular, the factors related to the 3D printed product, the properties of the 3D printer, and the properties of the materials are taken into consideration in this evaluation along with a number of related sub-factors. [22] Identified and evaluated the factors that enable cloud computing to be adopted in context. A fuzzy analytical hierarchy process (FAHP) was applied. Time to satisfy IT demand, security, and comparative advantage were found to be the most important factors. The results will help other institutions make adoption decision and gain a competitive advantage. In [23] this paper dealt with a multi-criteria hybrid decision-making model that includes choosing cloud services from among the available alternatives. The proposed methodology defined different cloud service grades based on QoS criteria using a new gray TOPSIS extended with AHP.[24] Improved the method of analyzing information security control with a formal approach using fuzzy AHP. This approach has been used to prioritize and identify the most relevant set of information security controls to meet the organization's information security requirements. In [25] the purpose of this paper is to develop cloud broker architecture for cloud service selection by creating a pattern for changing priorities of user preferences (UPs). To do this, I used a Markov chain to find the pattern. Quality of Service (QoS) related pattern for available services. [26] This study assessed the performance of companies by taking financial ratios and financial experts into consideration. So first, the weights of the criteria and sub-criteria related to financial ratios are obtained using Buckley's method of geometric mean of a column. Then the final ranking of these companies is determined by the TOPSIS, VIKOR and ELECTRE methods. In [27] this research applied fuzz set theory and the penetrated MCDM method - VIKOR method for evaluating online auction service quality. Quality of service is a combination of various features.

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There are many intangible traits that are difficult to measure. Thus, they called fuzzy group theory to benchmark, AHP for benchmark weights and VIKOR for ranking. In this paper [28], among the 28 alternatives that are determined by the person to buy, the best smart phone is based on three main criteria and 17 sub-criteria with the help of the MCDM two-stage approach. In the first stage, 28 smart phone alternatives were classified using the Analytical Network (ANP) process. In the second stage, a model is created that includes the four best alternatives to ANP. [36] Integrated fuzzy set theory with TOPSIS method for selecting cloud type and best cloud services provider.

3. RESEARCH METHODOLGY

The aim of this paper is to introduce a MCDM approach to select the best big data processing framework. AHP was introduced by Saaty since 1970's. AHP method has some important features, it is a simple method and its input data is easy to obtain [30], [31]. But AHP has some challenges like inconsistency, uncertainties, and ambiguity which solved through fuzzification [29], [32]. In this research we integrate the fuzzy set theory with AHP method as a hybrid approach and applying them in selection of the best processing framework adequate to financial services big data. The proposed methodology is shown in figure (1) and (2).

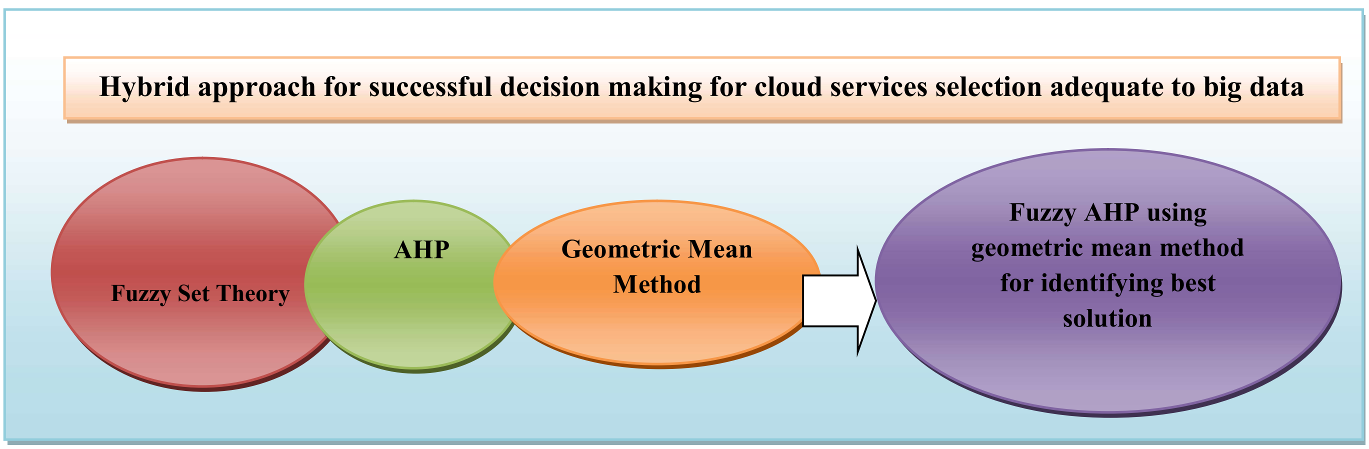

Figure 1: Proposed Hybrid Approach

Detailed steps of the hybrid approach are as follow see figure (2):

A.1. Collect the information about the problem aspects big data, financial services, cloud computing, and processing frameworks.

A. 2. Define goal, criteria, and alternatives.

Various studies have been conducted on determining the relevant criteria for evaluating and selecting big data processing frameworks. Based on this literature review [13], [14], these criteria are selected and favored to choose the most appropriate framework responding to the requirements of financial big data processing challenges as in table 1..

Table 1: Criteria Description for Selecting Best Frameworks

Index	Criteria	Description
C1	Availability (fault tolerance)	Networks, servers, and physical storage failure recovery to ensure high availability.
C2	Scalability	Means that every application or piece of infrastructure can be expanded to handle increased load.
C3	Performance	Data processing

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	(latency)	time.
C4	Computational complexity	Extensions such as data mining and business intelligence tools.
C5	Processing modes	Real-time and stream processing against historical data and time series data.
C6	Storage capacity	Work with different storage systems, how much data needs to be available in storage nodes at the same time.
C7	Security	Level of security and tools offered, data are protected, more or less valuable; platform is subject to strict security, compliance or governance requirements.
C8	Usability	Ease of use based on simple user interface.
C9	Sustainability	The cost associated with the skills maintenance, configuration, and adjustments to the level of agility in development, how much data the organization will need to manage and process today and in the future.
C10	Speed	processing time
C11	Compatibility	Integration with other systems and environments.
C12	Cost	What a customer wants, how much can be spent on.

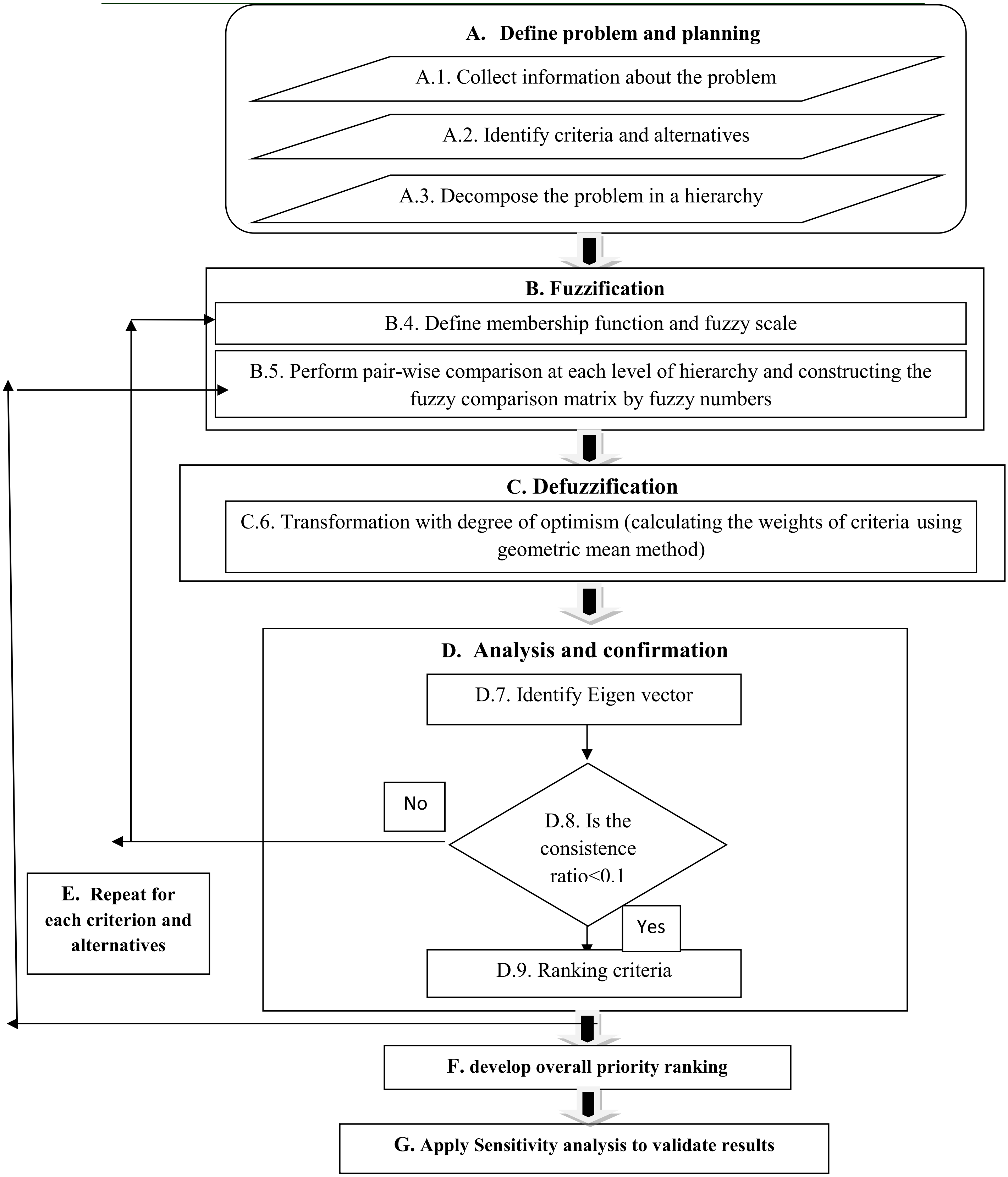

Figure 2: Proposed Methodology

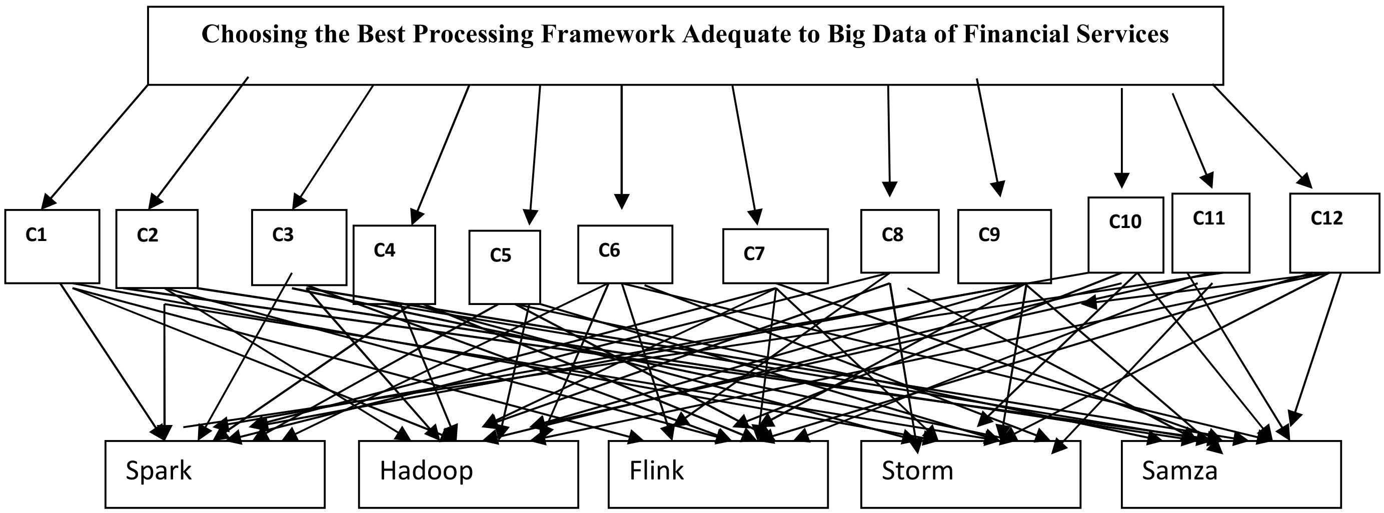

Figure 3: AHP Hierarchical Structure of Goal, Criteria, and Alternatives.

A.3. Decompose the problem into hierarchical structure as shown in figure (3).

a) Objective (goal).
b) Criteria.
c) And alternatives of frameworks.

B.4. Using fuzzy scale as shown in table (3) to construct pair-wise comparison between criteria and alternatives.

Fuzzy set theory (definition and basics) see figure (4):

Fuzzy set is defined as follows: If X is a universe of discourse and x is a particular element of X, then a fuzzy set a defined on X and can be written as a collection of ordered pairs

$A = \{(x, \mu_{\tilde{A}}(X)), x \in X\}$

(1)

The membership function fully (MF) defines the fuzzy set, A membership function provides a measure of the degree of similarity of an element to a fuzzy set Membership functions can – either be chosen by the user arbitrarily, based on the user's experience (MF chosen by two users could be different depending upon their experiences, perspectives, etc.) – Or be designed using machine learning methods (e.g., artificial neural networks, genetic algorithms, etc.) Fuzzy Sets (Continue) There are different shapes of membership functions; Triangular, Trapezoidal, Gaussian, etc. In this work we use triangular membership function, a triangular membership function is specified by three parameters {a, b, c} a, b and c represent the x coordinates of the three vertices of µA (x) in a fuzzy set A (a: lower boundary and c: upper boundary where membership degree is zero, b: the centre where membership degree is 1) [33], [34].

The operations of fuzzy sets A and B are listed as follows [35]:

- Union:

A∪B ↔ µA∪B =µA V µB.
(2)

- Intersection:

A∩B ↔ µA∩B =µA ∧µB.
(3)

- Complement:

Ã↔µÃ=1-µA.
(4)

- Algebraic Product:

A. B↔µ ΘA. B=µAµB.
(5)

- Algebraic Sum:

A+B↔µA+B=µA+µB-µAµB=1-(1-µA)(1-µB).
(6)

- Bounded-Sum:

A⊕ B↔µ A ⊕ B= 1 ∧ (µA+µB).
(7)

- Bounded-Difference:

AΘB↔µAΘB=V (µA-µB).
(8)

- Bounded-Product:

AΘB↔µAΘB=V (µA+µB-1).
(9)

Where the operations of V, A, +, -- represent max, min, arithmetic sum, and arithmetic difference, respectively.

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B.5. Perform pair-wise comparison at each level of hierarchy and constructing the fuzzy comparison matrix by fuzzy numbers as in table 4**.**

Firstly, A is a Decision matrix of dimensional nxn.

$$A = \begin{Vmatrix} a11 & \dots & a1n \\ a21 & \dots & a2n \\ an1 & \dots & ann \end{Vmatrix}$$

(10)

$[A_{ij}]$, where I,j=1,2,……,n

A_{ij}Is a Fuzzy number (l, m, u)

(11)

For reciprocal A^{-1}= (l, m, u) $^{-1}$= $(\frac{1}{u}, \frac{1}{m}, \frac{1}{l})$

(12)

A_{ij}=1 for i=j

(13)

C.6. Calculating the weights using fuzzy geometric mean method, see table 5:

Calculate the weights of criteria using geometric mean method by following steps [32].

Fuzzy geometric mean value (r_i): A1 ⊕ A2 ⊕ An =(l1,m1,U1)⊕(l2,m2,u2)⊕(ln,mn,un)=(l1*l2*…..*ln,m1*m2*…..*mn,u1*u2*…..*un)^$1/n$.

Where n is the number of criteria.

(14)

Fuzzy weights W_i

W_i= r_i⊕ (r1⊕ r2⊕rn) ^-1.

(15)

Centre of area (COA) of weights $W_i = \frac{l+m+u}{3}$

(16)

Normalized weights = $\frac{\mathrm{W_i}}{\sum_{n}^{i-1} \mathrm{W_i}}$

(17)

D.8. Calculate consistency:

Calculate consistency for pair-wise comparison across the consistency index (CI) and consistency ratio index (CRI), The AHP consistency test has been represented in the formulae below:

λmax=$\frac{1}{n}\sum_{j=1}^{n}\frac{A\mathrm{W_i}}{\mathrm{W_i}}$

(18)

CI=$\frac{\lambda max-n}{n-1}$

(19)

CR=$\frac{CI}{CRI}$

(20)

Where CRI see table 2;

If CR ≤ 0.1 the level of inconsistency is acceptable. Otherwise, the inconsistency is high and decision maker may need to estimate the elements of A to realize better consistency.

CR=$\frac{CI}{CRI}$ = 0**.06855** < 0.1

Figure (4) show that security criterion has the highest weight, cost criterion has the least weight, performance is the second, availability is the third, processing mode and speed has almost the same weight.

$$\mu_A(x) = \begin{Bmatrix} 0 & if\ x \le a \\ \frac{x-a}{b-a} & if\ a \le x \le b \\ \frac{c-x}{c-b} & if\ b \le x \le c \\ 0 & if\ x \ge c \end{Bmatrix}$$

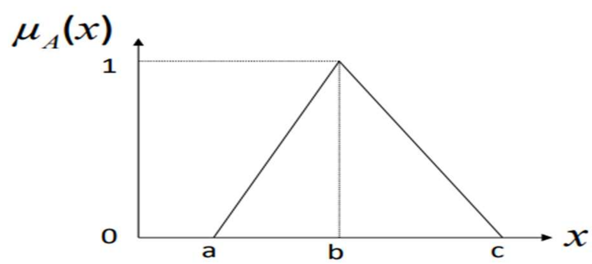

Figure 4: Fuzzy Set Theory

Table 2: Consistency Ratio Index (RCI)

n	3	4	5	6	7	8	9	10	11	12	13	14	15
RCI	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

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Table 3: Fuzzy Scale

Definition	Saaty scale	Fuzzy scale	Description
Equal	1	(1,1,1)	Two criteria are of equal importance
Moderate	3	(2,3,4)	Experience strongly favors one criteria over another
Strong	5	(4,5,6)	Experience and judgment strongly favor one activity over another
Very strong	7	(6,7,8)	Criteria is strongly favored and its dominance is demonstrated in practice
Extremely strong	9	(9,9,9)	The evidence favoring one criteria over another is of highest possible order of affirmation
Intermediate values	2	(1,2,3)	Whenever a compromise is needed
	4	(3,4,5)	
	6	(5,6,7)	
	8	(7,8,9)	

Table 4. Fuzzified Pair-wise Comparison Matrix

index	criteria	Availability	scalability	performance	Computational complixity	Processing mode	Storage capacity	security	usability	sustainability	speed	compatability	cost
1	C1	(1,1,1)	(2,3,4)	(1,2,3)	(2,3,4)	(1,1,1)	(1,2,3)	(1,1,1)	(1,2,3)	(1,1,1)	(1,2,3)	(1,2,3)	(3,4,5)
2	C2	(1/4,1/3,1/2)	(1,1,1)	(1/3,1/2,1)	(1,2,3)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(1/3,1/2,1)	(1,2,3)	(2,3,4)
3	C3	(1/3,1/2,1)	(1,2,3)	(1,1,1)	(2,3,4)	(1,2,3)	(1,2,3)	(1,1,1)	(3,4,5)	(2,3,4)	(1,1,1)	(3,4,5)	(4,5,6)
4	C4	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/4,1/3,1/2)	(1,1,1)	(1/3,1/2,1)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1,2,3)
5	C5	(1,1,1)	(1,1,1)	(1/3,1/2,1)	(1,2,3)	(1,1,1)	(1,2,3)	(1/3,1/2,1)	(2,3,4)	(2,3,4)	(1,1,1)	(2,3,4)	(4,5,6)
6	C6	(1/3,1/2,1)	(1,1,1)	(1/3,1/2,1)	(1,2,3)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1,2,3)	(1,2,3)	(1,1,1)	(1,2,3)	(2,3,4)
7	C7	(1,1,1)	(2,3,4)	(1,1,1)	(3,4,5)	(1,2,3)	(2,3,4)	(1,1,1)	(4,5,6)	(3,4,5)	(2,3,4)	(5,6,7)	(6,7,8)
8	C8	(1/3,1/2,1)	(1,1,1)	(1/5,1/4,1/3)	(1,1,1)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/6,1/5,1/4)	(1,1,1)	(1,2,3)	(1/3,1/2,1)	(1,2,3)	(1,2,3)
9	C9	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)	(1,1,1)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1/3,1/2,1)	(1,1,1)	(1/4,1/3,1/2)	(1,2,3)	(1,2,3)
10	C10	(1/3,1/2,1)	(1,2,3)	(1,1,1)	(2,3,4)	(1,1,1)	(1,1,1)	(1/4,1/3,1/2)	(1,2,3)	(2,3,4)	(1,1,1)	(3,4,5)	(4,5,6)
11	C11	(1/3,1/2,1)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1,1,1)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/7,1/6,1/5)	(1/3,1/2,1)	(1/3,1/2,1)	(1/5,1/4,1/3)	(1,1,1)	(1,2,3)
12	C12	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/6,1/5,1/4)	(1/3,1/2,1)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/8,1/7,1/6)	(1/3,1/2,1)	(1/3,1/2,1)	(1/6,1/5,1/4)	(1/3,1/2,1)	(1,1,1)

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Table 5: Criteria Weights and Ranking Using Fuzzy Geometric Mean Method

Index	Fuzzy geometric mean value (r_i)	Fuzzy weights (W_i)	Centre of area (COA)	Normalized W_i**(D.7)**	Ranking **(D.9)**
1	(1.2301,1.7994,2.2771)	(.06596,.1318,.2171)	.1383	.124	3
2	(.699,.91099,1.2009)	(.0375,.0667,.1145)	.0729	.0654	7
3	(1.3796,1.9421,2.5175)	(.0739,.1422,.24)	.152	.1363	2
4	(.4687,.6016,.8402)	(.0251,.0441,.0801)	.0498	.0447	9
5	(1.1096,1.5049,1.9718)	(.0595,.1102,.1879)	.1192	.1069	4
6	(.7154,1.0586,1.9718)	(.0384,.07752,.1457)	.0872	.0782	6
7	(2.1283,2.743,3.2908)	(.1141,.2009,.3138)	.2096	.1879	1
8	(.5086,.7103,1.009)	(.0273,.05201,.0962)	.0585	.0525	8
9	(.514,.06752,.9207)	(.0276,.0049,.0878)	.0401	.0359	11
10	(1.1225,1.489,1.896)	(.0602,.109,.1808)	.1167	.1046	5
11	(.3649,.4947,.7519)	(.0196,.0362,.07169)	.0425	.0381	10
12	(.2577,.3342,.4947)	(.0138,.0245,.0472)	.0285	.0256	12

E. Repeat steps B.5, C.6, D.7, D.8 and D.9 for all levels of the hierarchy see tables [6, 17].

Table 6:Alternatives Pair-wise Comparison Matrix Based on Availability Criterion

availability	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	1/3,1/2,1	2,3,4	1,1,1	1,1,1	0.6667,1.5,4	0.00459,0.0422,0.92332	0.32337	0.02809
Hadoop	1,2,3	1,1,1	3,4,5	1,2,3	1,2,3	3,32,135	0.02067,0.9009,31.16	10.694	0.9289
Flink	¼,1/3,1/2	1/5,1/4,1/3	1,1,1	1/3,1/2,1	1/3,1/2,1	0.00545,0.0206,0.1667	0.0000375,0.000579,0.03848	0.01303	0.01132
Storm	1,1,1	1/3,1/2,1	1,2,3	1,1,1	1,1,1	0.33,1,3	0.00227,0.02815,0.6925	0.24097	0.02093
samza	1,1,1	1/3,1/2,1	1,2,3	1,1,1	1,1,1	0.33,1,3	0.00227,0.02815,0.6925	0.24097	0.02093

CR=0.00358

Table 7:Alternatives Pair-wise Comparison Matrix Based on Scalability Criterion

Scalability	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	1/3,1/2,1	1/6,1/5,1/4	1/4,1/3,1/2	1/4,1/3,1/2	0.0034,0.01089,0.0625	0.000021,0.00028,0.00163	0.000644	0.000369
Hadoop	1,2,3	1,1,1	3,4,5	1,2,3	1,2,3	3,32,135	0.0186,0.8351,3.523	1.4589	0.83675
Flink	4,5,6	1/5,1/4,1/3	1,1,1	1/3,1/2,1	1/3,1/2,1	0.08712,0.3125,2	0.00054,0.0082,0.0522	0.02031	0.1165
Storm	2,3,4	1/3,1/2,1	1,2,3	1,1,1	1,1,1	0.6667,3,12	0.004,0.0783,0.3132	0.13183	0.0756
Samza	2,3,4	1/3,1/2,1	1,2,3	1,1,1	1,1,1	0.6667,3,12	0.004,.0783,0.3132	0.13207	0.0756

CR=0.08129

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Table 8:Alternatives Pair-wise Comparison Matrix Based on Performance Criterion

performance	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	3,4,5	1/3,1/2,1	¼,1/3,1/2	1/3,1/2,1	0.0825,0.33,2.5	0.000315,0.0044,0.2256	0.07677	0.00897
Hadoop	1/5,1/4,1/3	1,1,1	1/5,1/4,1/3	1/7,1/6,1/5	1/5,1/4,1/3	0.0011,0.0026,0.00719	0.00000419,0.000034,0.000649	0.0079	0.00092
Flink	1,2,3	3,4,5	1,1,1	1/6,1/5,1/4	1,1,1	0.5,1.6,3.75	0.00191,0.02118,0.3383	0.4432	0.05179
Storm	2,3,4	5,6,7	1,2,3	1,1,1	1,2,3	10,72,252	0.03817,0.9532,22.736	7.909	0.9242
Samza	1,2,3	3,4,5	1,1,1	1/6,1/5,1/4	1,1,1	0,5,1.6,3.75	0.00191,0.02118,0.3383	0.12047	0.01408

CR=0.011981

Table 9:Alternatives Pair-wise Comparison Matrix Based on Computational Complexity Criterion

Computational complexity	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	3,4,5	2,3,4	1,1,1	1,2,3	6,24,60	0.0452,0.48369,4.9	1.81	0.4548
Hadoop	1/5,1/4,1/3	1,1,1	1/3,1/2,1	1/5,1/4,1/3	¼,1/3,1/2	0.0033,0.0103,0.5445	0.000025,0.000208,0.00445	0.00156	0.000392
Flink	¼,1/3,1/2	1,2,3	1,1,1	¼,1/3,1/2	1/3,1/2,1	0.206,0.1089,0.75	0.000155,0.00219,.0613	0.02122	0.005332
Storm	1,1,1	3,4,5	2,3,4	1,1,1	1,2,3	6,24,60	0.0452,0.48369,4.9	1.8096	0.4547
Samza	1/3,1/2,1	2,3,4	1,2,3	1/3,1/2,1	1,1,1	0.2178,1.5,12	0.00164,0.0302,0.9803	0.3374	0.08478

CR=0.0067

Table 10. Alternatives Pair-wise Comparison Matrix Based on Processing Mode Criterion

Processing mode	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	3,4,5	1,1,1	2,3,4	1,2,3	6,24,60	0.0491,0.493,4.9	1.81	0.4918
Hadoop	1/5,1/4,1/3	1,1,1	1/5,1/4,1/3	¼,1/3,1/2	¼,1/3,1/2	0.0025,0.00681,0.02723	0.0000205,0.00014,0.002	0.000787	0.000214
Flink	1,1,1	3,4,5	1,1,1	2,3,4	1,2,3	6,24,60	0.0491,0.493,4.9	1.81	0.4918
Storm	¼,1/3,1/2	2,3,4	¼,1/3,1/2	1,1,1	1,1,1	0.125,0.33,1	0.00102,0.00678,0.0817	0.02983	0.00811
Samza	1/3,1/2,1	2,3,4	1/6,1/5,1/4	1,1,1	1,1,1	0.11,0.3,1	0.0009,0.0062,0.0817	0.0296	0.00804

CR=0.015062

Table 11: Alternatives Pair-wise Comparison Matrix Based on Storage Capacity Criteion

Storage capacity	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	4,5,6	1,2,3	1,2,3	2,3,4	8,60,216	0.033,0.9067,23.08	0.0543	0.9283
Hadoop	1/6,1/5,1/4	1,1,1	¼,1/3,1/2	¼,1/3,1/2	1/3,1/2,1	0.00344,0.0109,0.0625	0.000014,0.00016,0.00668	0.44335	0.00009
Flink	1/3,1/2,1	2,3,4	1,1,1	1,1,1	1,2,3	0.66,3,12	0.0027,0.0453,1.282	1.33	0.05206
Storm	1/3,1/2,1	2,3,4	1,1,1	1,1,1	1,2,3	0.6667,3,12	0.00276,0.0453,1.282	0.0023	0.01735
Samza	¼,1/3,1/2	1,2,3	1/3,1/2,1	1/3,1/2,1	1,1,1,	.02723,0.265,1.5	0.000113,0.00249,16.03	23.719	0.0021

CR=0.003642

Table 12: Alternatives Pair-wise Comparison Matrix Based on Security Criterion

Security	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	1/6,1/5, 1/4	1,1,1	1,1,1	3,4, 5	0.0,0.8,1.25	0.003,0.0189,0.2272	0.083	0.00799
Hadoop	1,2,3	1,1,1	1,2,3	1,2,3	4,5, 6	4,40,162	0.0241,0.9433,29.45	10.14	0.9759
Flink	1,1,1	1/6,1/5, 1/4	1,1,1	1,1,1	3,4, 5	0.5,0.8,1.25	0.003,0.0189,0.2272	0.083	0.00799
Storm	1,1,1	1/6,1/5, 1/4	1,1,1	1,1,1	3,4, 5	0.5,0.8,1.25	0.003,0.0189,0.2272	0.083	0.00799
Samza	1/5,1/4, 1/3	1/6,1/5, 1/4	1/5,1/4, 1/3	1/5,1/4, 1/3	1,1, 1	0.0013,0.0031,0.00898	0.0000078,0.000073,0.00163	0.00057	0.0000549

CR=0.00583

Table 13: Alternatives Pair-wise Comparison Matrix Based on Usability Criterion

Usability	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	3,4,5	1/6,1/5, 1/4	1,2,3	2,3,4	1,4.8,15	0.0031,0.04831,0.7754	0.2756	0.0464
Hadoop	11/5,1/4,1/3	1,1,1	1/5,1/4, 1/3	¼,1/3, 1/2	1/6,1/5, 1/4	0.0017,0.0041. 0.0136	0.000005,0.0007,0.000041	0.00025	0.000042
Flink	1,2,3	3,4,5	1,1,1	2,3,4	3,4,5	18,96,300	0.0557,,9663,15.51	5.51	0.9285
Storm	1/3,1/2, 1	2,3,4	¼,1/3,1/2	1,1,1	2,3,4	0.33,1.485,8	0.001,0.01495,0.4136	0.1432	0.0241
Samza	¼,1/3,1/2	1,2,3	1/5,1/4, 1/3	¼,1/3, 1/2	1,1,1	0.0125,0.0445, 0.2475	0.000039,0.00055, 0.01279	0.00446	0.00075

CR=*0.03305*

Table 14: Alternatives Pair-wise Comparison Matrix Based on Sustainability Criterion

Sustainability	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1, 1	1,1,1	1/3,1/2,1	¼,1/3,1/2	1/3,1/2,1	0.02723,0.0825,0.5	0.00017,0.0021,0.1061	.0361	0.0025
Hadoop	1,1, 1	1,1,1	1/3,1/2,1	¼,1/3,1/2	1/3,1/2,1	0.02723,0.0825,0.5	0.00017,00021,0.1061	.0361	0.0025
Flink	1,2, 3	1,2,3	1,1,1	1/3,1/2, 1	1,1,1	0.33,2,9	0.00202,0.04979, 1.909	1.9608	0.1368
Storm	2,3, 4	2,3,4	1,2,3	1,1,1	1,2,3	4,36,144	0.0245,0.8963,30	10.31	0.7194
Samza	1,2, 3	1,2,3	1,1,1	1/3,1/2, 1	1,1,1	0.33,2,9	0.00202,0.04979, 1.909	1.9608	0.1368

CR=0.00357

Table 15: Alternatives Pair-wise Comparison Matrix Based on Speed Criterion

Speed	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	5,6,7	2,3,4	3,4,5	3,4,5	90,288,700	0.1241,0.9795,7.691	2.9315	0.8967
Hadoop	1/7,1/6,1/5	1,1,1	1/5,1/4,1/3	¼,1/3, 1/2	¼,1/3, 1/2	0.001786,0.00454,0.0165	0.0000025,0.000015, 0.000181	0.3266	0.0999
Flink	¼,1/3,1/2	3,4,5	1,1,1	1,2,3	1,2,3	0.75,5.28,22.5	0.00103,0.01796,0.2472	0.00041	0.000125
Storm	1/5,1/4,1/3	2,3,4	1/3,1/2,1	1,1,1	1,1,1	0.132,0.375,1.32	0.00018,0.00128,0.0145	0.00532	0.001627
Samza	1/5,1/4,1/3	2,3,4	1/3,1/2,1	1,1,1	1,1,1	0.132,0.375,1.32	0.00018,0.00128,0.0145	0.00532	0.00163

CR=0.02109

Table 16: Alternatives Pair-wise Comparison Matrix Based on Compatability Criterion

Compatability	spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	¼,1/3,1/2	1,2,3	1/6,1/5,1/4	2,3,4	0.0833,0.396,1.5	0.00033,0.00519,0.1189	0.04147	0.00589
Hadoop	2,3,4	1,1,1	2,3,4	1,2,3	3,4,5	12,72,240	0.0474,0.9428,19.028	6.673	0.94737
Flink	1/3,1/2,1	¼,1/3,1/2	1,1,1	1/6,1/5,1/4	2,3,4	0.0275,0.765,0.5	0.00011,0.0100,0.0396	0.01657	0.00235
Storm	1,2,3	1/6,1/5,1/4	1,2,3	1,1,1	3,4,5	0.5,3.2,11.25	0.00197,0.0419,0.8919	0.3119	0.04428
Samza	¼,1/3,1/2	1/5,1/4,1/3	¼,1/3,1/2	1/5,1/4,1/3	1,1,1	0.0025,0.0068,0.02723	0.0000099,0.000089,0.00216	0.000753	0.000107

CR=0.03155

Table 17: Alternatives Pair-wise Comparison Matrix Based on Cost Criterion

Cost	Spark	hadoop	flink	storm	samza	ri	Fuzzy wi	COA	Normalized wi
Spark	1,1,1	1/6,1/5,1/4	1/3,1/2,1	¼,1/3,1/2	1/3,1/2,1	0.00458,0.0165,0.125	0.00001273,.0000159,0.0051	0.00176	0.00034
Hadoop	4,5,6	1,1,1	2,3,4	1,2,3	2,3,4	16,90,288	0.04525,0.8658,11.8	4.24	0.81023
Flink	1,2,3	¼,1/3,1/2	1,1,1	¼,1//3,1/2	1,1,1	0.0625,0.2178,0.75	0.0001777,0.0021,0.0307	0.0329	0.00629
Storm	2,3,4	1/3,1/2,1	2,3,4	1,1,1	2,3,4	8.33,13.5,64	0.02357,0.1299,2.623	0.92549	0.1769
samza	1,2,3	¼,1/3,1/2	1,1,1	¼,1/3,1/2	1,1,1	0.0625,0.2178,0.75	0.000177,0.0021,0.0307	0.0329	0.00629

CR=0.02022

F. Develop overall priority ranking, see table 18.

Result= local weights of criteria (W_i) *global weights of alternatives

$$\begin{bmatrix} W1 \\ W2 \\ Wn \end{bmatrix} * \begin{bmatrix} w11 & w12 & w1m \\ w21 & w22 & w2m \\ wm1 & wm2 & wmm \end{bmatrix},$$ where m is the number of alternatives (21)

Table 18:Fuzzy AHP Using Geometric Mean Method Results for Ranking Alternatives

Criteria / Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	Result	rankin
Weights of criteria	.124	.0654	.1363	.0447	.1069	.0782	.1879	.0525	.0359	.1046	.0381	.0256		
Spark	.02809	.000369	.00897	.4548	.4918	.9283	.00799	.0464	.0025	.8967	.00589	.00034	.24828	2
Hadoop	.9289	.83675	.00092	.000392	.000214	.00009	.9759	.000042	.0025	.0999	.94737	.81023	.42083	1
Flink	.01132	.1165	.05179	.005332	.4918	.05206	.00799	.9285	.1368	.000125	.00235	.00629	.1283869	4
Storm	.02093	.0756	.9242	.4547	.00811	.01735	.00799	.0241	.7194	.00162	.04428	.1769	.198838	3
Samza	.02093	.0756	.01408	.08478	.00804	.0021	.0000549	.00075	.1368	.00163	.000107	.00629	.019568	5

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4. VALIDATION OF RESULTS:

4.1. Compare The Hybrid Approach Results With The Results of Classical AHP.

We validate our proposal by using a comparison between classical AHP and FAHP as in section 4.1.2, and sensitivity analysis as in section 4.2.

4.1.1. Classical AHP method results:

Classical AHP has been applied on the same case study of financial services because this issue was not taken seriously before.

Table 19: Pairwise Ccomparison Matrix and Weights of Criteria

Index	criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	weights
1	C1	1	3	2	3	1	2	1	2	1	2	2	4	0.13301
2	C2	0.33	1	0.5	2	1	1	0.33	1	1	0.5	2	3	0.06236
3	C3	0.5	2	1	3	2	2	1	4	3	1	4	5	0.13505
4	C4	0.33	0.5	0.33	1	0.5	0.5	0.25	1	1	0.33	1	2	0.04071
5	C5	1	1	0.5	2	1	2	0.33	3	3	1	3	5	0.10152
6	C6	0.5	1	0.5	2	0.5	1	0.33	2	2	1	2	3	0.07213
7	C7	1	3	1	4	3	3	1	5	4	3	6	7	0.19583
8	C8	0.5	1	0.25	1	0.33	0.5	0.2	1	2	0.5	2	2	0.04999
9	C9	1	1	0.33	1	0.33	0.5	0.25	0.5	1	0.33	2	2	0.04966
10	C10	0.5	2	1	3	1	1	0.33	2	3	1	4	5	0.10281
11	C11	0.5	0.5	0.25	1	0.33	0.5	0.17	0.5	0.5	0.25	1	2	0.03427
12	C12	0.25	0.33	0.2	0.5	0.2	0.33	0.14	0.5	0.5	0.2	0.5	1	0.02264

Number of comparisons =66, principal eign value = 12.542, Consistency ratio (CR)=.06855

Table 20: Classical AHP Ranking of Alternatives

Criteria / alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	result	rankin
Criteria weights	.13303	.06236	.13505	.04071	.10152	.07213	.19583	.04999	.04966	.10282	.03427	.02264		
Spark	.1966	.07753	.11946	.31919	.3199	.3868	.15758	.20699	.10791	.4814	.12767	.07243	.22257	1
Hadoop	.35996	.35643	.046	.06828	.06345	.06934	.42604	.05296	.10791	.05324	.36606	.40443	.20916	3
Flink	.08346	.1529	.17469	.10934	.3199	.21221	.18231	.46923	.20658	.21432	.09773	.12114	.19401	4
Storm	.17998	.20657	.3659	.31919	.13788	.21221	.18231	.16155	.2878	.12552	.35069	.28086	.21789	2
Samza	.17998	.20657	.29395	.18401	.15887	.11944	.05176	.10927	.28978	.12552	.05786	.12114	.15637	5

4.1.2. Comparison between classical AHP and FAHP :

The results showed that classical AHP has the same evaluation of criteria weights as the fuzzy AHP, security criterion has the highest weight (0.1958 in classical AHP, and 0.1879 in FAHP), cost criterion has the least weight (0.0256), performance is the second (0.136), availability is the third (0.124), and processing mode and speed has almost the same weight, see Figures (5), and (6). But here the weights of the two criteria sustainability and usability are equal (0.04999), and their weights higher than compatibility criterion. In contrast to the hybrid approach in which the sustainability criterion is equal to compatibility criterion (0.0359) and their weights are less than usability criterion. Classical AHP results in Figure (8) show that Spark framework is the best (0.22257), Storm is the second (0.21789), Hadoop is the third (0.20916), and Samza is worst, In the Figure (7), the hybrid approach produced Hadoop framework is the

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best (0.42083), Spark is the second (0.24828), Storm is the third (0.198838), and Samza is worst. Flink and Samza got the same order in the two methods.

Table 21: Comparison of Criteria Weights by Classical AHP and FAHP

criteria	Criteria weights by clssical AHP	Criteria weights by FAHP
C1	0.13301	0.124
C2	0.06236	0.0654
C3	0.13505	0.1363
C4	0.04071	0.0447
C5	0.10152	0.1069
C6	0.07213	0.0782
C7	0.19583	0.1879
C8	0.04999	0.0525
C9	0.04966	0.0359
C10	0.10281	0.1046
C11	0.03427	0.0381
C12	0.02264	0.0256

Table 22: Comparison of Ranking Alternatives by Classical AHP and FAHP

ALTs	Weights by classical AHP	Ranking ALTs by classical AHP	Weights by FAHP	Ranking ALTs by FAHP
Spark	0.22257	1	0.24828	2
Hadoop	0.20916	3	0.42083	1
Flink	0.19401	4	0.1283869	4
Storm	0.21789	2	0.198838	3
Samza	0.15637	5	0.019568	5

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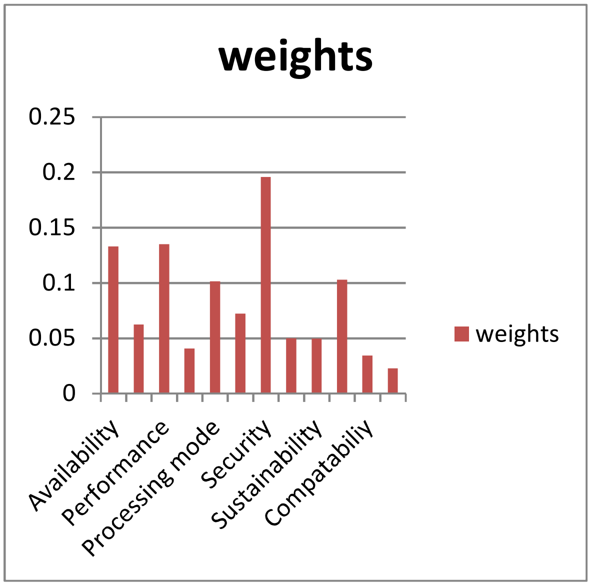

Figure 5: Weights of Criteria Using Classical AHP

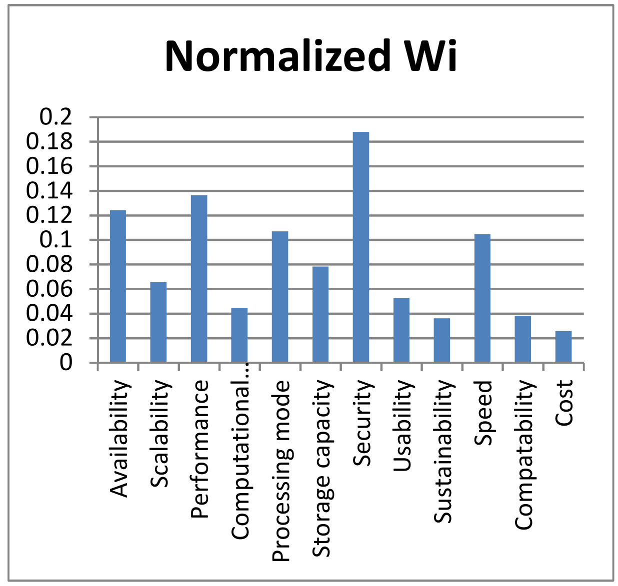

Figure 7: Fuzzy AHP Using Geometric Mean METHOD Evaluation and Ranking Alternatives

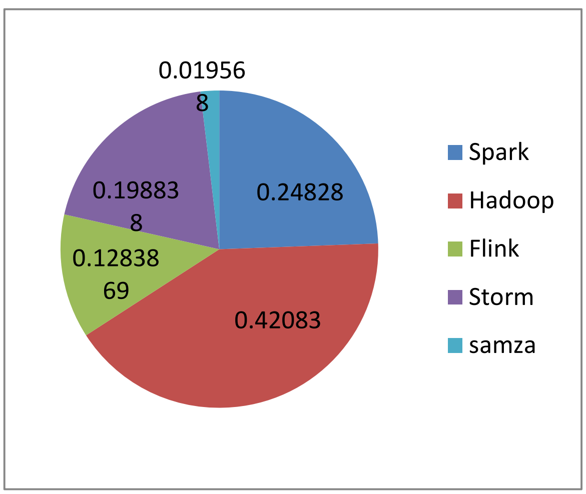

Figure 6: Weights of Criteria Using FAHP

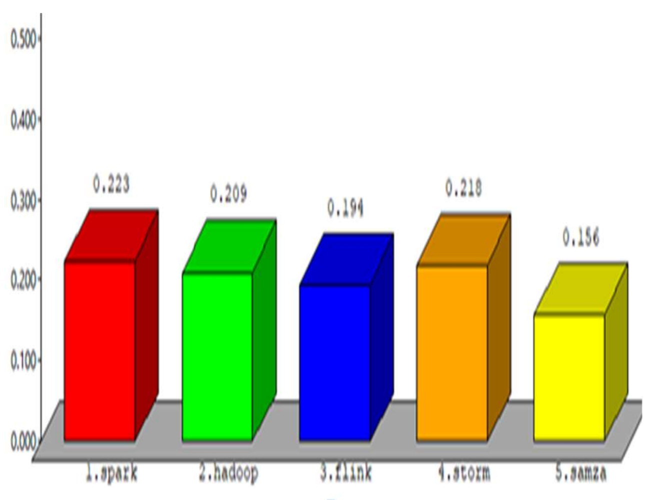

Figure 8: Classical AHP Ranking of Alternatives

4.2. Sensitivity analysis:

After comparing classical AHP and hybrid approach in previous section, different results was found. So we restored to sensitivity analysis which known as a tool to confirm robustness of any mathematical model [37]. Sensitivity analysis was applied on classical approach results based on security criterion, see figures (9), and (10), Hadoop framework has a higher security, availability, scalability,and compatability level, but has most expensive cost when compared to other frameworks. Spark has highest storage capacity , speed, and best processing mode for lower cost. Flink has best usability, and processing mode for lowest cost. Storm has best performance, and sustainability. In Figure (10), sensitivity analysis shows that rank reverse point is really interesting because it means that when the

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security criterion weight is above 0.5 instead of having the best option spark then storm, we start having the best option Hadoop then Spark and the change of priorities gets even more visible when security weight increases. This raking of alternatives is quite similar to results of our proposal which proves its robustness and effectiveness.

5. CONCLUSION:

Fuzzy geometric mean method was integrated with AHP to select best big data processing framework. We assigned weights to criteria using Fuzzy scale and geometric mean method then used AHP to rank alternatives. Security criterion has the highest weight (0.1879) and performance criterion is the second. Hadoop framework is the best (0.42083), Spark is the second rank (0.24828), and Samza is the worst. The hybrid approach can be used effectively for evaluating cloud frameworks. This research helps decision makers in enterprises, especially in financial sector where security criterion has the most attention to select the best cloud framework for processing their sensitive data. We integrate fuzzy geometric mean method and AHP to solve uncertainty and inconsistency problems. At the end we applied sensitivity analysis on alternatives based on security criterion to validate results of our proposal. With calculating consistency ratio and sensitivity analysis, the hybrid approach has been approved to be consistent and robust.

6. LIMITAION:

The hybrid approach in this paper was produced under the limit of financial services only.

7. FUTURE WORK:

We are looking forward to doing a lot of experiments using other different MCDM methods on the same research problem and in different fields such as healthcare and others.

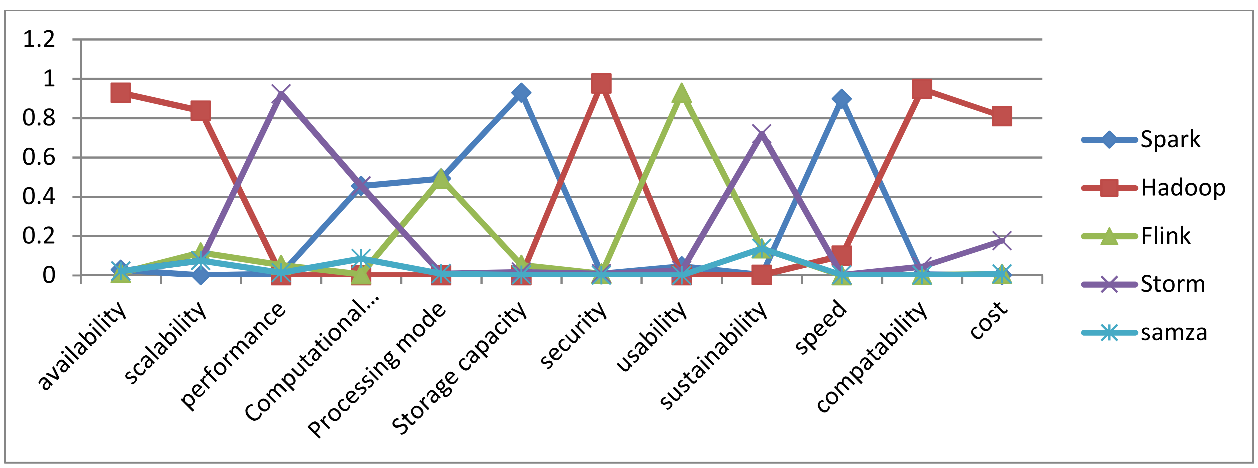

Figure 9: Criteria Weights In Different Alternatives.

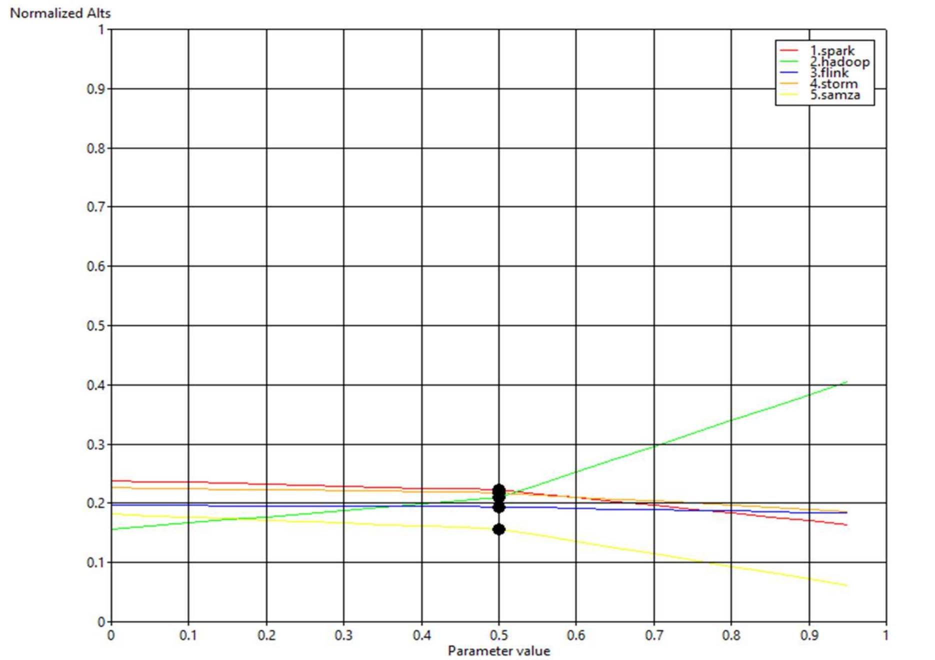

Figure 10: Sensitivity Analysis According To Security Criterion

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