Enterprise Architecture Framework Selection for Collaborative Freight Transportation Digitalization: A Hybrid FAHP-FTOPSIS Approach

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***Abstract*—Collaborative freight transportation plays a crucial role for Logistic Service Providers (LSPs) seeking to enhance profitability and service quality, yet it faces challenges at strategic, operational, and technical levels. Digital transformation creates opportunities to overcome these hurdles by extending collaboration beyond physical logistics to encompass information management and digital transformation. Enterprise Architecture Frameworks (EAFs) offer promising solutions by providing a holistic view of various levels within such ecosystems and ensuring alignment between information systems and strategic objectives. However, selecting the right EAF is a complex and critical step. This study introduces an innovative approach for selecting an Enterprise Architecture (EA) framework to support the development of a collaborative freight transportation platform. It emphasizes the importance of adopting a systematic EA methodology in the digitalization of the freight transportation sector. The decision-making process integrates established techniques such as the Analytic Hierarchy Process (AHP) and the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS). Applied to a case study involving a Moroccan logistics company, the approach demonstrates effectiveness in framework selection. The study's findings underscore the method's significance as a valuable tool for organizations embarking on digital transformation through EA, offering adaptability across diverse industries and contexts.**

Keywords*—Digital transformation; freight transportation; enterprise architecture; multi-criteria decision-making; analytic hierarchy process; fuzzy technique for order of preference by similarity to ideal solution

I. Introduction

In the evolving landscape of freight transportation, digital transformation is fueled by advancements in Information and Communication Technologies (ICT) and a growing demand for more efficient and sustainable logistics operations [1], [2], [3]. This work is motivated by the imperative to introduce a decision-making method for the meticulous selection of a fitting Enterprise Architecture (EA) framework essential for underpinning the development of a collaborative freight transportation platform. The proposed method integrates two well-known multicriteria decision-making techniques: the Analytic Hierarchy Process (AHP) and the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS). The overarching goal is to aid organizations in the evaluation and ranking of candidate EA frameworks, considering diverse criteria such as functionality, interoperability, scalability, and adaptability.

At the heart of this endeavor lies the challenge of striking a delicate balance amid the conflicting requirements of diverse stakeholders, including IT managers, business analysts, and end-users, in the meticulous selection of an apt EA framework. Moreover, the selection process involves a multitude of criteria often shrouded in subjectivity and resistant to quantification. To surmount these challenges, the authors advocate for a group decision-making approach that actively involves various stakeholders in the selection process. This approach employs a nuanced blend of quantitative and qualitative methods to assess and rank candidate EA frameworks.

The primary contributions of this work are twofold. Firstly, the proposed decision-making method integrates AHP and F-TOPSIS techniques for selecting a suitable EA framework for a collaborative freight transportation platform. Secondly, the application of this method to a case study involving a Moroccan logistics company demonstrates its effectiveness in selecting an appropriate EA framework. The findings from this work can provide valuable insights for other organizations seeking to drive digital transformation through EA.

In the realm of collaborative freight transport, a strategic approach employed by logistics service providers (LSPs) to enhance profitability and service quality, various challenges hinder its effectiveness. These challenges encompass difficulties in finding suitable partners, establishing fair gain-sharing mechanisms, and fostering trust in resource sharing [4]. Simultaneously, the imperative for companies to undertake digital transformation projects to align with innovation trends adds complexity. LSPs are compelled to extend collaboration beyond physical flow, managing information and undergoing digital transformation, further complicating alignment among strategies, business, and systems for multi-stakeholders.

Enterprise architecture frameworks (EAFs) play a pivotal role in addressing such complexity, offering a holistic view of the system and aligning information systems with strategic and business requirements. However, selecting the appropriate EAF is a challenging task due to the plethora of frameworks available, each with its strengths and weaknesses. Existing works on EAF selection often lack specificity to concrete contexts and needs, either proposing abstract evaluation models or performing global EAF comparisons. This paper addresses these gaps by evaluating EAFs in the context of designing an ongoing digital platform for collaborative freight transportation (DCRFT).

The methodology involves a hybrid Multi-criteria Group Decision Making approach, comprising two phases. In the first phase, criteria are identified through a literature review enriched by expert interviews, and the Analytic Hierarchy Process (AHP) is employed to determine their importance weights. In the second phase, Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS) is used to rank the EAF alternatives. Fuzzy set theory is adopted to overcome ambiguity stemming from subjective judgments and incomplete information among decision-makers [5]. Throughout both phases, group decision aggregation techniques are applied and illustrated. The comprehensive approach presented in this work stands as a valuable resource for organizations navigating the intricate landscape of digital transformation in collaborative freight transportation.

The remainder of this paper is organized as follows: Section II introduces the background of Multi-Criteria Decision Making (MCDM) and Enterprise Architecture Framework. Section III provides a literature review related to EAF evaluations. Section IV presents the AHP and F-TOPSIS method, describing the procedural steps of the proposed approach. The results of the case study are discussed in Section V. Section VI presents a sensitivity analysis. Finally, Section VII concludes the article and sheds light on future works.

II. Background

In this section, an in-depth examination of the Enterprise Architecture Framework unfolds, revealing its fundamental principles and practical applications. The focus then shifts towards exploring Digitalizing Freight Transportation: Strategic Solutions with Enterprise Architecture, where the transformative influence of digital technologies on logistics and supply chain management takes center stage. To conclude, attention is directed to the concept of Multi-Criteria Decision Making (MCDM), shedding light on its pertinence within the realm of Driving Digital Transformation in Freight Transportation. Collectively, these sections foster a comprehensive understanding of the study's foundational components, laying the groundwork for a nuanced exploration of their intricate interconnections and implications within the dynamic landscape of freight transportation.

A. Enterprise Architecture Framework

Zachman [6] defines architecture as a set of design elements essential for outlining an object to meet quality requirements and ensure maintenance throughout its utility period. It involves tools for understanding the current state and aiming for a better future state. Enterprise Architecture (EA) provides a holistic organizational view, distinct from technical architecture, and addresses stakeholder concerns [7].

EA acts as a strategic tool, assisting organizations in defining their current (As-is) and desired future (To-be) states regarding infrastructures, processes, and digital capabilities. It aligns strategic and business levels with operational and system implementations, crucial in the current digital landscape for guiding organizational change and facilitating digital transformation [8].

In turbulent environments, sustained competitive advantages require organizational flexibility and resilience [9]. EA can support adaptive capacities and facilitate the progression to higher-level capabilities by re-conceptualizing itself through an enterprise's ecological adaptation perspective.

Moreover, EA provides governance encompassing IT principles, architecture, investment management, and planned strategy, closely tied to organizational business values, yielding benefits in visibility, productivity, and efficiency of business processes and information systems [10].

Numerous studies have linked various advantages to the implementation of enterprise architecture. In a literature review conducted by [11], success factors and benefits of enterprise architecture were identified. These include heightened responsiveness and flexibility to change, enhanced alignment between the business model and IT, reduced IT costs, optimized utilization of IT resources, improved risk management, enhanced integration/interoperability, more favorable outcomes from business and strategic initiatives, refined business processes, and diminished complexity in IT. Notably, these effects are typically indirect, pervasive throughout the entire enterprise, and accrue over an extended period.

B. Digitalizing Freight Transportation: Strategic Solutions with Enterprise Architecture

In the logistics and supply chain management domain, Freight Transportation entails the movement of goods across diverse modes like trucks, trains, ships, and planes [12]. Mode selection considers factors such as distance, urgency, and the nature of goods. Efficient freight transportation is pivotal for seamless goods flow within the supply chain, a critical aspect of the broader logistics network. Driving Digital Transformation in Freight Transportation involves leveraging technological advancements for enhanced efficiency, transparency, and overall effectiveness [13]. This encompasses integrating digital tools, data analytics, and automation to optimize routes, manage inventory, and streamline communication in the freight transportation ecosystem.

The road freight transport sector is witnessing substantial economic growth, playing a crucial role in modern economies and influencing global competitiveness. The surge in e-commerce and globalization has heightened transport demands, urging companies in various modes to enhance associated services. This dynamic presents persistent challenges for road freight transport trucks. Economically, operators must optimize efficiency to maximize profits and minimize empty trips. Environmentally, efforts are required to reduce CO_2 emissions, mitigate road congestion, and curb noise pollution. Socially, enhancing accessibility and physical mobility is essential for improving the quality of life for logistics workers and the global population [14], [15], [16], [17].

Trucking companies are compelled to align with "Industry 4.0," emphasizing digital manufacturing and high-level automation [18]. Information exchange and integration of the intelligent logistics chain are critical, with information flow management central in data-driven transportation operations.

In this evolving context, freight transportation demands novel organizational and technological approaches for effective management and adaptation to digital changes [19].

Digital platforms offer productivity in implementing collaborative and intelligent environments, transforming organizational business models through partner discovery, accelerated information sharing, optimization, and tracking of logistical operations [20], [21]. This transition poses technological, organizational, and strategic challenges, requiring a comprehensive methodology. “Enterprise Architecture” (EA) serves as a crucial tool, offering a holistic view of the organization while ensuring alignment between strategic objectives and technical solutions.

In this evolving freight transportation landscape, selecting a tailored Enterprise Architecture Framework (EAF) is paramount. Beyond immediate challenges, the chosen EAF should provide a roadmap for navigating digital transformation, addressing operational complexities and ensuring seamless integration of innovative technologies, efficient processes, and strategic objectives. This approach steers the transformation towards a more agile and responsive freight transportation ecosystem.

C. Multi-Criteria Decision Making (MCDM)

Within the realm of Multi-Criteria Decision Making (MCDM), its application extends beyond traditional problem-solving domains, finding relevance in the context of Driving Digital Transformation in Freight Transportation. MCDM, as a sophisticated evaluation process, serves as a valuable tool for decision-makers facing the intricate challenges of adopting and implementing digital technologies in the freight transportation sector. The inherent complexity of this industry, marked by diverse operational facets and evolving technological landscapes, makes MCDM an ideal approach for navigating the intricacies of decision-making.

In the realm of freight transportation, where uncertainties and risks are inherent, MCDM proves to be an essential mechanism for evaluating digital transformation strategies. By integrating both qualitative and quantitative criteria, decision-makers can systematically assess and compare various alternatives in selecting an Enterprise Architecture Framework (EAF). The decision-maker’s active role in expressing preferences and values aligns with the dynamic nature of the freight transportation ecosystem, ensuring that the chosen EAF is not only technologically adept but also aligns with the organization’s strategic objectives.

The study conducted by Zavadskas et al. [22] further emphasizes the versatility of MCDM as a structuring tool, providing a systematic method for solving complex problems. As witnessed in various sectors such as project management, urban planning, and supplier selection, MCDM’s robust framework for decision-making proves to be adaptable to diverse contexts. In the freight transportation industry, where the stakes are high and the need for informed decision-making paramount, MCDM emerges as a strategic ally in navigating the digital transformation landscape. By incorporating MCDM principles, decision-makers can ensure that the selected Enterprise Architecture Framework aligns cohesively with the multifaceted demands of the industry, contributing to a seamless and effective digital evolution in freight transportation.

The application of Multi-Criteria Decision-Making (MCDM) methodologies, such as AHP and TOPSIS, has proven effective in various technological contexts beyond freight transportation. Recent research has utilized these methods for selecting tools in chatbot development, considering factors like scalability, performance, and maintainability [23]. Similarly, another study applied MCDM techniques to evaluate cross-platform mobile development frameworks, addressing complex decision-making scenarios involving conflicting criteria [24]. These examples highlight the adaptability and utility of MCDM approaches in supporting strategic decision-making across diverse domains.

Building upon earlier applications of MCDM methodologies in freight transportation, recent advancements have extended their utility to simulation-based analytics frameworks and the evaluation of AI-driven tools for predictive and prescriptive decision-making [25]. These methods, including hybrid Intuitionistic Fuzzy-AHP approaches, enable logistics companies to optimize their operations by leveraging real-time data and advanced analytical capabilities. Such integrations facilitate the selection of solutions tailored to complex requirements, bridging traditional decision-making processes with AI-enhanced logistics systems [25].

III. Related Works

Recently, Organizations use EA to maximize their organizational, business and IT project value. It brings multitude benefits over time, from abstract aspect such business–IT alignment and decision-making improvement to measurable advantage such as reducing costs [26], [27]. Now with the continuous and unpredictable market change, EA is needed more than ever.

It has the potential to orchestrate business and digital transformations of an organization in order to act efficiently in the new market environment [28].

However, during the last decades many EA frameworks are developed, which makes the selection of suitable frameworks a difficult decision task. Several works in literature focus on evaluating or comparing some well-known EAF in general basis [29], [30]. Some of them evaluate EAFs on the main architectural components such Metamodel, principles, views and specification documents [31], [32], [33], while others establish comparison based on quality attribute or practice criteria [34], [35], [36], [37], [38]. Table I presents a list of these works. It mentions the studied EAFs, the application domain, and whether the author used process MCDM.

As shown in the Table I, there is a limited collection of popular frameworks chosen by the authors. It is observed also that few studies use MCDM methods to select EAFS. In addition, there is a lack of studies that focus on EAFs comparison according to digital transformation issues.

Moreover, during the literature review we have identified a list of the most chosen criteria that may be useful to compare and select EAFs. Table II presents our classification of these criteria as well as papers that cover them.

TABLE I. EAFS COMPARISON WORKS

Paper	Compared Frameworks	With Selection Process	Use of MCDM Method	Application Domain
[39]	ZF, TEAF, TOGAF, and DODAF	Yes	X	Energy
[40]	ZF, FEAF, TOGAF, SAGA, GEA, MFCNO			Public organization
[36]	ZF, TOGAF, FEAF, DoDAF, and Gartner	Yes		General
[33]	ZF, TOGAF, TEAF, FEAF, DoDAF			General
[41]	ZF, ARIS			General
[31]	DoDAF, GERAM, FEAF, TOGAF, IAF, MIT, Gartner, DYA			General
[32]	ZF, TOGAF, FEAF, DoDAF, TEAF	Yes		General
[34]	ZF, TOGAF, FEAF, DODAF, EAP	Yes		General
[38]	ZF, TEAF, LTGAF, DoDAF, FEAF			General
[42]	ZF, TOGAF, FEAF	Yes	X	Education
[35]	ZF, TOGAF, MODAF, NAF, DODAF, UAF, FEAF	Yes		General
[43]	TOGAF, Zachman, MODAF, FEAF, DoDAF, NAF	Yes		General
[37]	Zachman, TOGAF, DODAF, Gartner, EAP, FEAF, TEAF, LTGAF, GERAM, E2AF	Yes		General
[44]	TOGAF, FEA, Gartner, EAP, DoDAF			General

TABLE II. CLASSIFICATION OF CRITERIA TAKEN FROM LITERATURE

Criteria	Subcriteria	Papers
Modeling	Meta model/Reference model	[34], [32], [35], [43], [45], [46]
	Procedure model	[39], [34], [32], [33],[43], [45], [46]
	Modeling technique/Modeling languages openness/Standardization	[39], [34], [32], [35], [38], [43], [47]
	Viewpoint	[33], [37], [45], [48]
Technical Quality	Alignment	[29], [30], [37], [38], [42], [43], [45], [48]
	Integrity	[29], [30], [32], [38], [43], [49]
	Reusability	[39], [30], [38], [43]
	Security	[30], [38], [43]
	Scalability	[39], [30], [38], [42], [43]
	Reliability	[29], [30], [38]
	Efficiency	[29], [32], [38], [42]
	Adaptability	[34], [30], [42]
Functional Quality	Business drivers	[30], [32], [42], [46]
	Business requirements	[32], [43], [48]
	Architecture knowledge base	[32], [47], [49]
Concepts	Artifacts	[37], [48]
	Governance	[34], [32], [37], [43], [45], [46], [48]
	Repository	[37], [43], [48]
	Strategy	[37], [43], [48]
Usability	Taxonomy	[34], [32], [33], [37], [46], [48]
	Principles practice	[34], [32], [46]
	Understandability from different stakeholders' viewpoints	[32], [33]
	Ease of use	[39], [34], [30], [32], [33], [35], [42], [46]
	Architecture Definition and Understanding	[34], [29], [30], [33], [35], [42], [46]
	Architecture guidelines/documentation	[33], [39], [30], [32], [37], [43], [46], [47], [48]
Technology trends	Cloud	[50]
	Mobile IT and IoT	[50]

Due to the diverse requirements and specifications inherent in various sectors, each use case necessitates a tailored Enterprise Architecture Framework (EAF) that aligns precisely with its unique needs and objectives [51]. Consequently, this article employs advanced Multi-Criteria Decision-Making (MCDM) methods to discern the most suitable EAF for crafting a digital and versatile platform that fosters collaboration in freight transportation (DCRFT). To address this complex system within the realm of digital transformation projects, we advocate for a group decision method, integrating the Analytical Hierarchy Process (AHP) and the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (FTOPSIS). This approach aims to meticulously select an EAF that not only describes but also effectively designs the intricate aspects of the system.

IV. METHODOLOGY

This paper uses two stages method AHP and F-TOPSIS as detailed below (Fig. 1). Firstly, we defined fourteen sub-criteria through a literature review enriched by the opinions of four experts. Similarly, four popular EAF were chosen as alternatives to compare. Thereafter, AHP is used to determine the importance weights of criteria. Further, these weights are used in the ranking process based on F-TOPSIS algorithm. The process uses a group decision techniques and fuzzy set theory to overcome the ambiguity due to subjective and imprecise judgments among the decision-makers participating in the evaluation. Fig. 1 illustrates the steps of the two process phases.

A. Problem Definition

This work is an integral part of an ongoing project aimed at developing a digital and versatile platform designed to support collaborative efforts in the transportation of goods. The platform's distinguishing feature is its polymorphic capacity, accommodating a wide range of collaboration forms involving various actors, approaches, rules, and objectives.

Designing a digital project with such richness in terms of complexities necessitates the use of an enterprise architecture framework (EAF). Given the considerable number of available EAFs and the various factors influencing their selection, we have opted to initially employ a Multiple Criteria Decision-Making (MCDM) method. This approach will guide us in

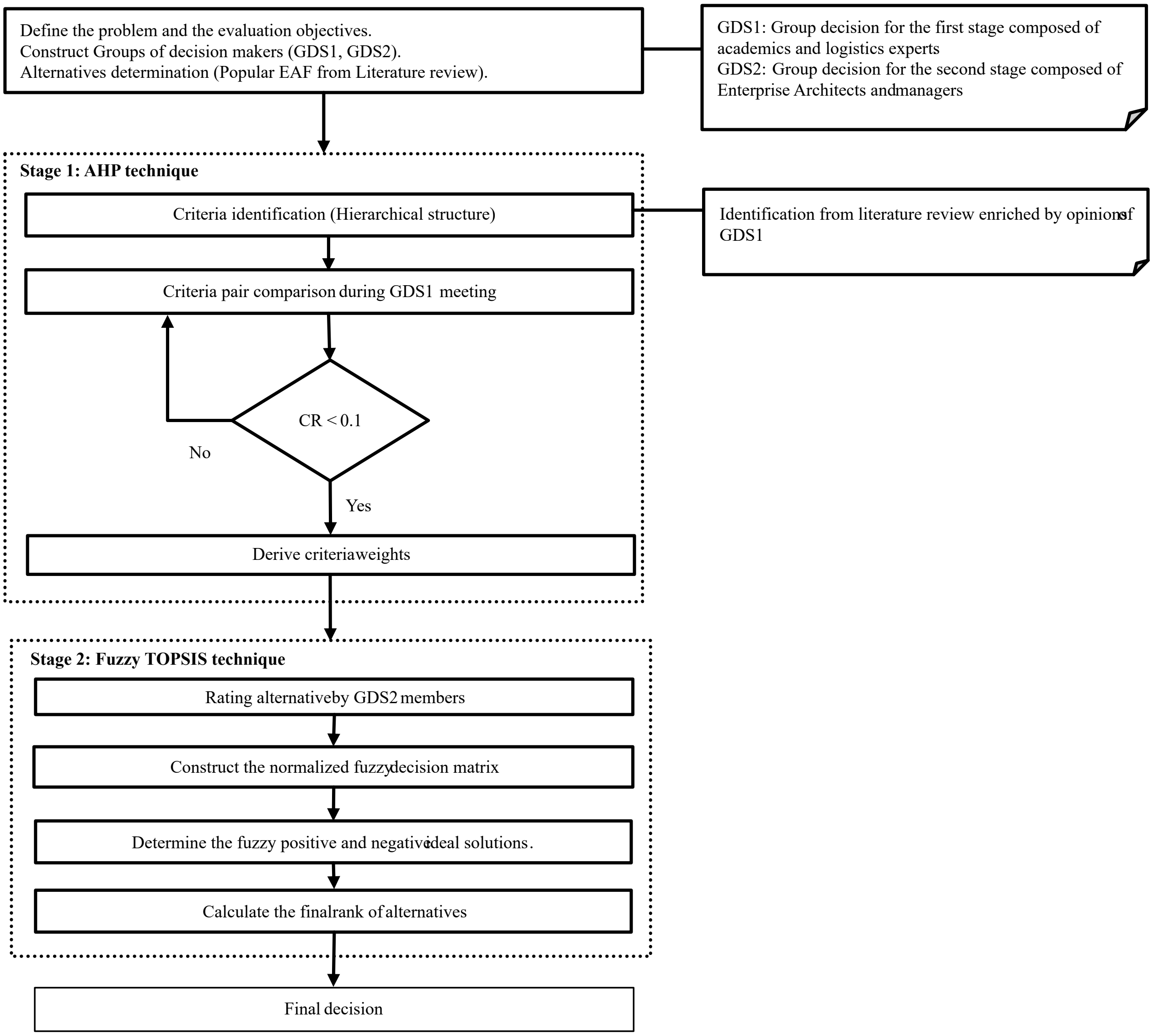

Fig. 1. Proposed integrated methodology for enterprise architecture framework selection.

systematically evaluating and selecting the most appropriate framework to meet the specific requirements of this project.

B. Phase 1: AHP Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) [52] stands out as one of the most extensively utilized MCDM methods. This method empowers decision makers to break down a complex problem into a more manageable hierarchical structure with a minimum of three levels: the problem objective at the top level, criteria and sub-criteria at the middle level, and alternatives at the bottom level.

Within this process, prioritization of criteria occurs, and each alternative is assigned scores based on these criteria. This evaluation is conducted through pairwise comparisons, employing a predefined Saaty scale (Table III) [53], with a simultaneous check for the consistency of judgments. Ultimately, a weighted score is computed for each alternative, providing a comprehensive and informed basis for decision-making.

TABLE III. SAATY SCALE [53]

Definition	**Intensity of importance**
Equally important	1
Moderately more important	3
Strongly more important	5
Very strong more important	7
Extremely more important	9
Intermediate more important	2, 4, 6, 8

In this study we have applied AHP only to establish criteria importance weights. The process steps are described below:

Step 1: Considering a set of criteria $C = \{Ci/i = 1, 2, 3 \ldots n\}$, we define the matrix $M(n \times n)$ as result of a

TABLE IV. RANDOM INDEX

n	3	4	5	6	7	8	9	11	12	13	14	15
RI	0.52	1.88	1.11	1.25	1.34	1.40	1.48	1.51	1.53	1.55	1.57	1.58

paire-wise comparison for each criterion.

$$M = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nn} \end{bmatrix}, \quad x_{ii} = 1, \quad x_{ji} = \frac{1}{x_{ij}}, \quad x_{ij} \neq 0 \tag{1}$$

Step 2: calculate the priority vectors and drive Coherence Index (CI) as well as the Coherence Ratio (CR):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2}$$

where $\lambda_{\max}$ is the largest Eigen value.

$$CR = \frac{CI}{RI} \tag{3}$$

Where *RI (Random Index)* is a value that depends on the number of criteria as illustrated in Table IV.

Step 3: If the Consistency Ratio is less than or equal to 10% establish the criteria weight importance Else back to step 1 and review the paire wise comparison.

C. Phase 2: Fuzzy TOPSIS

TOPSIS stands out as a well-established and widely applied Multiple Criteria Decision-Making (MCDM) method. Its popularity arises from its user-friendly interface, rapid alternative evaluation process, low mathematical complexity, and adaptability for seamless integration with other methods. The computational process of TOPSIS is designed to identify an optimal solution that minimizes the distance to the positive ideal solution (PIS) and maximizes the separation from the negative ideal solution (NIS). The PIS represents a solution composed of the best weights assigned to the criteria, while the NIS is a solution obtained by aggregating the worst values assigned to the criteria [54].

Nevertheless, in many real-world decision problems, the expressions of individuals' opinions often manifest in linguistic terms, introducing vagueness and subjectivity. Consequently, the precision of criteria weights and evaluations for given alternatives becomes challenging. To address imprecise judgments, the MCDM method incorporates a fuzzy theory concept introduced in [55]. In fuzzy theory, instead of assigning a binary "totally true" or "totally false" value to an imprecise decision, a degree of membership is assigned. This degree of membership is typically represented by the interval [0, 1], where 0 signifies "totally false," 1 denotes "totally true," and the intervening values refer to intermediate degrees of truth. In this paper, we utilized the triangular fuzzy number (TFN), defined by the triplet (a, b, c), where a and c are successively the lower and upper bounds, and b is the center where the value is 1 (refer to Fig. 2).

Fig. 3 present the membership function of linguistic terms and Table V shows their correspondence on triangular fuzzy numbers.

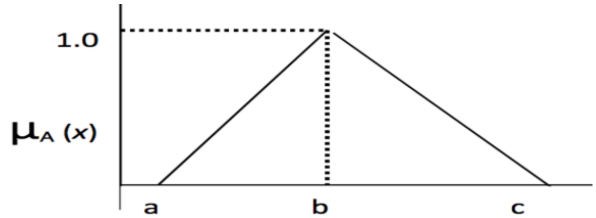

Fig. 2. Triangular fuzzy number.

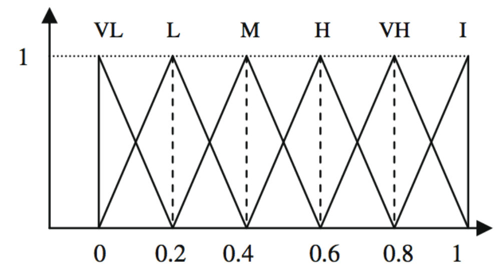

Fig. 3. Membership functions of linguistic terms.

$$\mu_A(x; a, b, c) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & a \leq x \leq b \\ \frac{c-x}{c-b}, & b \leq x \leq c \\ 0, & c \leq x \end{cases} \tag{4}$$

TABLE V. LINGUISTIC VALUES AND CORRESPONDING FUZZY NUMBERS

Linguistic variables	**Corresponding Fuzzy numbers**
Very low	(0,0,0.2)
Low	(0,0.2,0.4)
Medium	(0.2,0.4,0.6)
High	(0.4,0.6,0.8)
Very high	(0.6,0.8,1)
Excellent	(0.8,1,1)

Considering E the set benefit criteria (greater value is better) and F set of cost criteria (lower value is better) and let $W = (w_1, w_2, \ldots, w_n)$ be the vector of criteria weights concluded from phase 1. The steps of TOPSIS process are as follows [56]:

Step 1: Considering K DMs, define K fuzzy decision matrix $X^k = \left(x_{ij}^k\right)$, where x_{ij}^k is TFN that represent the rating assigned to alternative i for criterion j by decision maker k.

Therefore, the rating of alternatives with respect to each criterion can be calculated as $x_{ij} = \frac{1}{K}\left(x_{ij}^1 + x_{ij}^2 + \cdots + x_{ij}^K\right)$. Each x_{ij}^k is defined by triplet $\left(a_{x_{ij}}, b_{x_{ij}}, c_{x_{ij}}\right)$.

Step 2: By using linear normalization, we build the normalized fuzzy decision matrix $N = (n_{ij})$ as below

$$n_{ij} = \begin{cases} \left(\frac{a_{x_{ij}}}{\max_i c_{x_{ij}}}, \frac{b_{x_{ij}}}{\max_i c_{x_{ij}}}, \frac{c_{x_{ij}}}{\max_i c_{x_{ij}}}\right) & \text{si } j \in E \\ \left(\frac{\min_i a_{x_{ij}}}{c_{x_{ij}}}, \frac{\min_i a_{x_{ij}}}{b_{x_{ij}}}, \frac{\min_i a_{x_{ij}}}{a_{x_{ij}}}\right) & \text{si } j \in F \end{cases} \tag{5}$$

Step 3: The weighted normalized fuzzy matrix V is calculated by multiplying the columns of the normalized fuzzy decision matrix N and the correspondent weights $w_j \in R$ satisfying $\sum_{j=1}^{n} w_j = 1$. $V = (v_{ij})$

Where $v_{ij} = n_{ij} \cdot w_j = (a_{n_{ij}}, b_{n_{ij}}, c_{n_{ij}}) \cdot w_j = (a_{n_{ij}} \cdot w_j, b_{n_{ij}} \cdot w_j, c_{n_{ij}} \cdot w_j)$

Step 4: Deduce the fuzzy positive and negative ideal solution as follows:

$$\text{PIS} = (v_1^+, v_2^+, \ldots, v_n^+) \tag{6}$$

$$\text{NIS} = (v_1^-, v_2^-, \ldots, v_n^-) \tag{7}$$

Where $v_j^+ = \max_i v_{ij}$ and $v_j^- = \min_i v_{ij}$

Step 5: determine the distances of each alternative A_i from PIS and NIS

$$d_i^+ = \sum_{j=1}^{n} dd(v_{ij}, v_j^+) \tag{8}$$

$$d_i^- = \sum_{j=1}^{n} dd(v_{ij}, v_j^-) \tag{9}$$

By using the formula that calculates the distance dd between two positive TFNs $A = (a_A, b_A, c_A)$ and $B = (a_B, b_B, c_B)$:

$$dd(A, B) = \sqrt{\frac{1}{3}\left[(a_A - a_B)^2 + (b_A - b_B)^2 + (c_A - c_B)^2\right]} \tag{10}$$

Step 6: Deduce the relative closeness of alternative A_i to the ideal solution PIS :

$$RC_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{11}$$

Step 7: based to the relative group closeness, rank the alternatives A_i and select the best one that have the halue of RC_i.

D. Criteria Identification

During the literature review, it has been noticed that there is no one Enterprise Architecture Framework as all-purpose solution. The choice depends on the requirements and situations being processed. In this perspective, we have focused in the first step to depict the important criteria that will be a keys factor to consider in our situation. Therefore, we have identifying fourteen criteria from literature review enriched by academics and logistics experts' opinions see Table VI.

E. Alternatives

In this section, a brief description is provided for four enterprise architecture frameworks selected as alternatives in this study. These frameworks were chosen based on their frequent inclusion in comparative analyses (refer to Table I).

- **A1: The Zachman Framework** is an enterprise architecture model officially introduced by [6]. It presents a logical structure in a bidimensional matrix format, where the first dimension comprises six columns representing the six fundamental questions: What, How, Where, Who, When, and Why. Each of these questions is then explored through six perspectives. This results in a taxonomy that categorizes the various architectural artifacts necessary for developing and designing an information system to help the organization manage change and ensure alignment between business and IT.
- **A2: TOGAF, The Open Group Architecture Framework**, developed in 1995, has become an industry standard widely adopted for designing, governing, and constructing architectures for organizations. It categorizes enterprise architecture into four domains: Business, Application, Data, and Technology architecture [46]. The TOGAF transformation process is anchored in the Architecture Development Method (ADM) engine, comprising cyclical phases to define, plan, implement, and ultimately manage changes from the current "As-is" architecture to the desired "To-be" architecture [57].
- **A3: DoDAF, The Department of Defense Architecture Framework**, is developed specifically for the United States Department of Defense. While its primary focus is on defense applications, its applicability extends to other domains as well. DoDAF introduces a set of products and a view model designed to serve as tools for visualizing, understanding, and assimilating the broad scope and complexities of an architecture. These products are organized into four views: All View (AV), Operational View (OV), Systems View (SV), and Technical Standards View (TV). Notably, DoDAF is well-suited for large, complex system architectures and stands out for its incorporation of "operational views" [58].
- **A4: The Federal Enterprise Architecture Framework (FEAF)** was developed by the US Federal Chief Information Officers (CIO) Council with the aim of constructing and supporting integrated systems architectures. Its primary objective is to enhance the management and exchange of information within government and federal agencies, facilitating efficient and prompt service delivery to clients and citizens by improving access to information. FEAF is structured around six reference models: performance, business, data, application, infrastructure, and security reference models [58].

V. RESULTS

The evaluation process commences with the establishment of the GDS1 group decision for the initial stage, comprising two academic experts and two logistics experts. During in-depth discussions, the group constructs a hierarchical structure consisting of 14 criteria. Subsequently, they populate the upper and lower triangle elements of the pairwise comparison matrix (refer to Table VII). The comparison ratings are deliberated upon, reaching a consensus within the group.

The consensual weight for each criterion is obtained after establishing the normalized matrix (Table VIII) with (CR= 0,09084).

TABLE VI. CRITERIA DEFINITIONS

Criteria	Description
(C1) Agility challenges	Concern agile design and development of the system in an iterative and flexible manner.
(C2) Requirement taxonomy	Due to the multitude of actors, objectives, and strategies, in addition to the multitude of functionalities between business, operational, and technical: the requirements analysis and design must be granular.
(C3) Focused views	Putting in place appropriate views for each stakeholder to facilitate their understanding, focus, and participation in development.
(C4) Ease of use	The simplicity of the design tool or method.
(C5) Architecture guidelines	Design tool and method guide and documentation.
(C6) Cost	The cost of framework adoption and use.
(C7) Ontology architecture definition	Given the different cultures and vocabularies of the stakeholders, it is better to define an ontology facilitating integration of new keywords.
(C8) Data extensibility and integration	Ability to be extensible in terms of data integration of different types and structures.
(C9) Process and system scalability	Ability to manage and integrate business, operational, or administrative processes.
(C10) Metamodeling and abstractions	The framework level of abstraction to facilitate extensibility during development.
(C11) Artefact interoperability	Facility of interoperability between elements of the solution in terms of data and processes.
(C12) Heterogeneous IoT technology integration	The capabilities of the EAF to handle IoT architecture as an emerging technology widely used in the logistic fields.
(C13) Cloud/Fog cloud implementation	As an emerging technology, Cloud is very practical for this kind of application. This criterion concerns the capabilities of the EAF to implement Cloud architectures.
(C14) Facility to integrate Big data analytics	The capabilities of the EAF to integrate Big data analytics.

TABLE VII. PAIRWISE COMPARISON MATRIX

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C1	1	1/5	1/3	5	5	1/3	3	1/2	1/2	2	1/4	1	1/4	¼
C2	5	1	3	7	8	4	7	2	3	4	2	2	3	3
C3	3	1/3	1	5	6	3	5	1/4	1/6	3	1/3	1/4	1/2	1/6
C4	1/5	1/7	1/5	1	2	1/4	3	1/5	1/5	1/4	1/5	1/6	1/7	1/7
C5	1/5	1/8	1/6	1/2	1	1/4	1/2	1/5	1/5	1/4	1/6	1/6	1/7	1/7
C6	3	1/4	1/3	4	4	1	1/2	1/4	1/4	1/2	1/3	1/4	1/6	1/6
C7	1/3	1/7	1/5	1/3	2	2	1	1/3	1/4	1/2	1/4	1/6	1/6	1/6
C8	2	1/2	4	5	5	4	3	1	1	2	1/2	2	1/2	½
C9	2	1/3	6	5	5	4	4	1	1	3	1/2	2	1/2	½
C10	1/2	1/4	1/3	4	4	2	2	1/2	1/3	1	1/3	1/3	1/5	1/5
C11	4	1/2	3	5	6	3	4	2	2	3	1	1/2	1/2	½
C12	1	1/2	4	6	6	4	6	1/2	1/2	3	2	1	1/2	½
C13	4	1/3	2	7	7	6	6	2	2	5	2	2	1	2
C14	4	1/3	2	7	7	6	6	2	2	5	2	2	1/2	1

TABLE VIII. NORMALIZED MATRIX AND PRIORITIES WEIGHTS

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	Eigen weight
C1	0,03	0,04	0,01	0,08	0,07	0,01	0,06	0,04	0,04	0,06	0,02	0,07	0,03	0,03	0,043
C2	0,17	0,20	0,11	0,11	0,12	0,10	0,14	0,16	0,22	0,12	0,17	0,14	0,37	0,32	0,176
C3	0,10	0,07	0,04	0,08	0,09	0,08	0,10	0,02	0,01	0,09	0,03	0,02	0,06	0,02	0,057
C4	0,01	0,03	0,01	0,02	0,03	0,01	0,06	0,02	0,01	0,01	0,02	0,01	0,02	0,02	0,018
C5	0,01	0,03	0,01	0,01	0,01	0,01	0,01	0,02	0,01	0,01	0,01	0,01	0,02	0,02	0,012
C6	0,10	0,05	0,01	0,06	0,06	0,03	0,01	0,02	0,02	0,02	0,03	0,02	0,02	0,02	0,033
C7	0,01	0,03	0,01	0,01	0,03	0,05	0,02	0,03	0,02	0,02	0,02	0,01	0,02	0,02	0,020
C8	0,07	0,10	0,15	0,08	0,07	0,10	0,06	0,08	0,07	0,06	0,04	0,14	0,06	0,05	0,082
C9	0,07	0,07	0,23	0,08	0,07	0,10	0,08	0,08	0,07	0,09	0,04	0,14	0,06	0,05	0,089
C10	0,02	0,05	0,01	0,06	0,06	0,05	0,04	0,04	0,02	0,03	0,03	0,02	0,02	0,02	0,035
C11	0,13	0,10	0,11	0,08	0,09	0,08	0,08	0,16	0,15	0,09	0,08	0,04	0,06	0,05	0,093
C12	0,03	0,10	0,15	0,10	0,09	0,10	0,12	0,04	0,04	0,09	0,17	0,07	0,06	0,05	0,087
C13	0,13	0,07	0,08	0,11	0,10	0,15	0,12	0,16	0,15	0,15	0,17	0,14	0,12	0,22	0,134
C14	0,13	0,07	0,08	0,11	0,10	0,15	0,12	0,16	0,15	0,15	0,17	0,14	0,06	0,11	0,122

The next stage consists to scores each alternative against these criterions by EA experts (3 architects), they are asked to rank the four alternatives by using linguistic terms which are transformed to triangular fuzzy number (Tables IX, X, XI). By considering the C6 as cost criteria and the rest of criteria as benefit criteria. We have applied the operations mentioned above (Eq. (5), (6) and (7)) and we obtain the normalized matrix as illustrated in Table XII and Table XIII.

Finally, by applying the Eq. (8), (9) and (11), we have obtained the relative closeness of all alternatives A_i to PIS as depicted in Table XIV, the best rank is assigned to A2- Togaf framework.

TABLE IX. FUZZY RANKING MATRIX : EXPERT 1: CEO, CHIEF ARCHITECT AT EA PRINCIPALS, USA

	A1			A2			A3			A4		
C1	0,00	0,20	0,40	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C2	0,80	1,00	1,20	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C3	0,60	0,80	1,00	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C4	0,60	0,80	1,00	0,60	0,80	1,00	0,60	0,80	1,00	0,60	0,80	1,00
C5	0,80	1,00	1,20	0,60	0,80	1,00	0,60	0,80	1,00	0,60	0,80	1,00
C6	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C7	0,80	1,00	1,20	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C8	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C9	0,60	0,80	1,00	0,60	0,80	1,00	0,60	0,80	1,00	0,60	0,80	1,00
C10	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C11	0,60	0,80	1,00	0,60	0,80	1,00	0,20	0,40	0,60	0,20	0,40	0,60
C12	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C13	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C14	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40

VI. DISCUSSION

The results of the first phase illustrated that the taxonomy of needs and the granularity of details according to the different views of the project stakeholders is the most important criterion to be considered when choosing an EAF adapted to this project. In second place comes the ability to develop emerging cloud, IoT and Big data architectures as they are the indispensable solutions to build powerful, efficient and effective digital platforms. Also, in the same level of importance there are the scalability of the system in terms

TABLE X. FUZZY RANKING MATRIX : EXPERT 2: EXPERIENCED ARCHITECT AND BUILDER OF PROFESSIONAL COMMUNITIES, AUSTRIA

	A1			A2			A3			A4		
C1	0,40	0,60	0,80	0,60	0,80	1,00	0,20	0,40	0,60	0,20	0,40	0,60
C2	0,80	1,00	1,20	0,40	0,60	0,80	0,60	0,80	1,00	0,60	0,80	1,00
C3	0,60	0,80	1,00	0,40	0,60	0,80	0,80	1,00	0,60	0,20	0,40	0,60
C4	0,60	0,80	1,00	0,20	0,40	0,60	0,20	0,40	0,60	0,40	0,60	0,80
C5	0,20	0,40	0,60	0,80	1,00	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C6	0,20	0,40	0,60	0,40	0,60	0,80	0,20	0,40	0,60	0,40	0,60	0,80
C7	0,00	0,20	0,40	0,60	0,80	1,00	0,60	0,80	1,00	0,40	0,60	0,80
C8	0,20	0,40	0,60	0,40	0,60	0,80	0,40	0,60	0,80	0,40	0,60	0,80
C9	0,20	0,40	0,60	0,60	0,80	1,00	0,60	0,80	1,00	0,20	0,40	0,60
C10	0,00	0,20	0,40	0,60	0,80	1,00	0,60	0,80	1,00	0,20	0,40	0,60
C11	0,40	0,60	0,80	0,40	0,60	0,80	0,60	0,80	1,00	0,00	0,20	0,40
C12	0,40	0,60	0,80	0,40	0,60	0,80	0,20	0,40	0,60	0,20	0,40	0,60
C13	0,20	0,40	0,60	0,40	0,60	0,80	0,20	0,40	0,60	0,40	0,60	0,80
C14	0,20	0,40	0,60	0,40	0,60	0,80	0,20	0,40	0,60	0,20	0,40	0,60

TABLE XI. FUZZY RANKING MATRIX : EXPERT 3: ENTERPRISE ARCHITECT, MOROCCO

	A1			A2			A3			A4		
C1	0,00	0,00	0,20	0,00	0,20	0,40	0,00	0,00	0,20	0,00	0,00	0,20
C2	0,60	0,80	1,00	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20
C3	0,40	0,60	0,80	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C4	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C5	0,00	0,00	0,20	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C6	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20
C7	0,40	0,60	0,80	0,20	0,40	0,60	0,20	0,40	0,60	0,20	0,40	0,60
C8	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20
C9	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20
C10	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C11	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40	0,00	0,20	0,40
C12	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,20	0,40	0,60
C13	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20
C14	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20	0,00	0,00	0,20

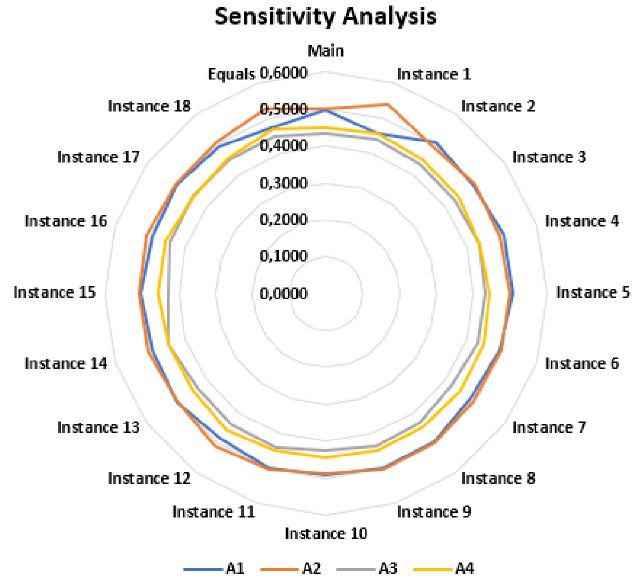

Fig. 4. Sensitivity analysis under different criteria weights.

of data, processes and the interoperability of artefacts.

In the second stage the evaluation of the four frameworks by the Enterprises architects demonstrated that all the frameworks have strengths and weaknesses and puts the Togaf framework as the closest to the context of our need. The decision makers also highlight in all the frameworks a low level of implementation of the new architectures founder of the digital transformation, namely the cloud, Iot and big data. This requires EA must reinvent itself and keep pace with technological evolution and remain a key tool for future business design [59].

To evaluate the current ranking, the Fuzzy VIKOR and Fuzzy Promethee methods are applied to the same problem, and their results are then compared. Details of these methods can be found in [60], [61]. For criterion weighting, the evaluation results obtained by the AHP approach are used. The results of the AHP-fuzzy VIKOR and AHP-fuzzy Promethee approaches are presented in Table XV.

Analysis of Table XV reveals that the ranking of the two best alternatives remains unchanged, while that of the other alternatives varies. This suggests that the proposed methodology produces a solution very similar to the AHP-fuzzy VIKOR and AHP-fuzzy Promethee methodologies, confirming the robustness of the approach.

VII. SENSITIVITY ANALYSIS

In this study, a two-stage decision-making process is employed, integrating both the Analytic Hierarchy Process (AHP) and Fuzzy-TOPSIS methodologies, and subjected to a sensitivity analysis. During this analysis, criteria weights, initially derived using the AHP technique, are exchanged between two criteria while keeping the others constant. For each instance, the resulting values (v+, v-, d+ and d-) are computed to illustrate the updated outcomes. This process is iterated for twenty combinations, maintaining identical weights for specific criteria out of the fourteen, thereby providing a comprehensive evaluation. The details of all instances are succinctly presented in Table XVI, and the resulting rankings of the alternatives are visually depicted in Fig. 4.

Table XVI and Fig. 4 underscore that the initial instance effectively encapsulates the primary findings of the combined AHP-Fuzzy-TOPSIS approach. Notably, among the nineteen instances, Alternative A2 consistently attains the highest score. The sensitivity analysis reveals a significant divergence in the ranking of alternatives when equal weights are assigned to sub-criteria. Despite this, the evaluations suggest that the decision-making process remains generally robust to changes in criteria weights, with Alternative A2 consistently emerging as the preferred choice across various scenarios.

VIII. CONCLUSION

In conclusion, this project has significant implications for logistics and digitalization. By leveraging Enterprise Architecture (EA) as a key tool to address digital transformation challenges, the ongoing project focuses on developing a digital collaboration platform for freight transport. The complexity lies in choosing a suitable Enterprise Architecture Framework (EAF) amid numerous options. The paper introduces a decision-making method that integrates the Analytical Hierarchy Process (AHP) and the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (F-TOPSIS) within a group multi-criteria process to select the most suitable EAF for successful project implementation.

The study's findings offer advantages for projects engaging in digital transformation through EA. A suitable EAF is crucial in providing a comprehensive view of the system and aligning information systems with strategic and business needs. The study identifies the Zachman framework as the closest match among the four EAFs examined, offering valuable insights for modeling complex digital systems through EAFs. Ultimately, implementing an appropriate EA framework can assist Logistics Service Providers (LSPs) in improving profitability and

TABLE XII. PIS END NIS CALCUL

	A1			A2			A3			A4			V-	V+
C1	0,01	0,02	0,03	0,02	0,03	0,04	0,01	0,02	0,03	0,01	0,02	0,03	**0,01**	**0,04**
C2	0,11	0,14	0,18	0,03	0,05	0,08	0,04	0,06	0,09	0,04	0,06	0,09	**0,03**	**0,18**
C3	0,03	0,04	0,06	0,01	0,02	0,04	0,02	0,03	0,03	0,01	0,02	0,03	**0,01**	**0,06**
C4	0,01	0,01	0,02	0,01	0,01	0,02	0,01	0,01	0,02	0,01	0,01	0,02	**0,01**	**0,02**
C5	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	**0,01**	**0,01**
C6	0,03	0,10	0,20	0,07	0,13	0,23	0,03	0,10	0,20	0,07	0,13	0,23	**0,03**	**0,23**
C7	0,01	0,02	0,02	0,01	0,01	0,02	0,01	0,01	0,02	0,01	0,01	0,02	**0,01**	**0,02**
C8	0,02	0,04	0,07	0,03	0,05	0,08	0,03	0,05	0,08	0,03	0,05	0,08	**0,02**	**0,08**
C9	0,03	0,05	0,07	0,05	0,06	0,09	0,05	0,06	0,09	0,03	0,05	0,07	**0,03**	**0,09**
C10	0,00	0,01	0,02	0,01	0,02	0,03	0,01	0,02	0,03	0,01	0,02	0,03	**0,00**	**0,03**
C11	0,04	0,07	0,09	0,04	0,07	0,09	0,03	0,06	0,08	0,01	0,03	0,06	**0,01**	**0,09**
C12	0,02	0,04	0,08	0,02	0,04	0,08	0,01	0,03	0,07	0,02	0,05	0,09	**0,01**	**0,09**
C13	0,02	0,06	0,12	0,04	0,08	0,13	0,02	0,06	0,12	0,04	0,08	0,13	**0,02**	**0,13**
C14	0,02	0,05	0,10	0,03	0,07	0,12	0,02	0,05	0,10	0,02	0,05	0,10	**0,02**	**0,12**

TABLE XIII. THE WEIGHTED NORMALIZED FUZZY MATRIX

	A1			A2			A3			A4			max cji	min aij
C1	0,13	0,27	0,47	0,27	0,47	0,67	0,13	0,27	0,47	0,13	0,27	0,47	0,67	
C2	0,73	0,93	1,13	0,20	0,33	0,53	0,27	0,40	0,60	0,27	0,40	0,60	1,13	
C3	0,53	0,73	0,93	0,20	0,40	0,60	0,33	0,53	0,53	0,13	0,33	0,53	0,93	
C4	0,40	0,60	0,80	0,27	0,47	0,67	0,27	0,47	0,67	0,33	0,53	0,73	0,80	
C5	0,33	0,47	0,67	0,53	0,73	0,73	0,33	0,53	0,73	0,33	0,53	0,73	0,73	
C6	**0,07**	**0,20**	**0,40**	**0,13**	**0,27**	**0,47**	**0,07**	**0,20**	**0,40**	**0,13**	**0,27**	**0,47**		**0,07**
C7	0,40	0,60	0,80	0,33	0,53	0,73	0,33	0,53	0,73	0,27	0,47	0,67	0,80	
C8	0,13	0,27	0,47	0,20	0,33	0,53	0,20	0,33	0,53	0,20	0,33	0,53	0,53	
C9	0,27	0,40	0,60	0,40	0,53	0,73	0,40	0,53	0,73	0,27	0,40	0,60	0,73	
C10	0,07	0,27	0,47	0,27	0,47	0,67	0,27	0,47	0,67	0,13	0,33	0,53	0,67	
C11	0,33	0,53	0,73	0,33	0,53	0,73	0,27	0,47	0,67	0,07	0,27	0,47	0,73	
C12	0,13	0,27	0,47	0,13	0,27	0,47	0,07	0,20	0,40	0,13	0,33	0,53	0,53	
C13	0,07	0,20	0,40	0,13	0,27	0,47	0,07	0,20	0,40	0,13	0,27	0,47	0,47	
C14	0,07	0,20	0,40	0,13	0,27	0,47	0,07	0,20	0,40	0,07	0,20	0,40	0,47	

TABLE XIV. FINAL RANKING

Alternatives	**RCI**	**Ranking**
A1	0,4980	2
A2	0,4997	1
A3	0,4341	4
A4	0,4481	3

service quality, ensuring adaptability to innovation trends for competitiveness.

This study introduces a robust method for selecting a pivotal Enterprise Architecture (EA) framework, steering the digital transformation of the freight transportation sector. Leveraging the Analytic Hierarchy Process (AHP) and Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (F-TOPSIS), the approach systematically evaluates and ranks candidate EA frameworks. Application to a case study involving a Moroccan logistics company demonstrated the method's practicality and relevance in real-world scenarios.

Looking ahead, there are exciting opportunities for further research and refinement of the method. The dynamic nature of technology and business environments calls for criteria adaptable to change. Future work could explore the inclusion of dynamic criteria, ensuring selected EA frameworks remain relevant amid evolving technologies. Integrating machine learning techniques into the decision-making process represents another promising avenue for future research. Leveraging historical data and trends, organizations can make informed predictions about the future suitability of EA frameworks.

Further exploration could assess the scalability and adaptability of the proposed EA selection approach across different geographic regions and logistics sectors. Testing its effectiveness in small-to-medium-sized enterprises (SMEs) and large multinational logistics firms would highlight its versatility. The integration of emerging technologies such as blockchain, IoT, and AI could significantly enhance EA frameworks in logistics, improving transparency, efficiency, and security, and driving digital transformation. Future work should also consider including environmental and social criteria in the decision-making process, aligning EA frameworks with green logistics and sustainability objectives. Addressing high-risk factors like geopolitical disruptions, cybersecurity threats, and market volatility through robust risk assessments would further enhance the resilience of EA frameworks. Additionally, exploring hybrid EA frameworks could lead to tailored solutions that promote scalability, flexibility, and adaptability. Finally, expanding this research to other industries, such as healthcare, manufacturing, and energy, would provide valuable comparative insights into the broader application of EA frameworks. Long-term studies that evaluate key performance indicators (KPIs) such as cost reduction, efficiency, and customer satisfaction would help assess the sustainability and effectiveness of these frameworks.

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TABLE XV. EVALUATION RESULTS VIA AHP-FUZZY VIKOR AND AHP-FUZZY PROMETHEE

Alternatives	Ranking of the present study	AHP-Fuzzy VIKOR		AHP-Fuzzy PROMETHEE	
		VIKOR index Q	Ranking	Net flow	Ranking
A1	2	0.3327	2	-0.0098	2
A2	1	0.2241	1	0.5581	1
A3	3	0.9752	3	-0.2530	3
A4	4	1.0000	4	-0.2954	4

TABLE XVI. RESULTS OF SENSITIVITY ANALYSIS

	Alternatives frameworks				Ranking
	A1	A2	A3	A4	
Instance 1 (Main)	0,4980	0,4997	0,4341	0,4481	A2 - A1 - A4 - A3
Instance 2	0,456034	0,539087	0,441156	0,455069	A2 - A1 - A4 - A3
Instance 3	0,5053	0,4951	0,4357	0,4471	A1 - A2 - A4 - A3
Instance 4	0,495342	0,50159	0,433236	0,446364	A2 - A1 - A4 - A3
Instance 5	0,5077	0,4973	0,4363	0,4357	A1 - A2 - A3 - A4
Instance 6	0,5055	0,4978	0,4317	0,4420	A1 - A2 - A4 - A3
Instance 7	0,495776	0,498447	0,433537	0,449904	A2 - A1 - A4 - A3
Instance 8	0,484433	0,496299	0,423687	0,448482	A2 - A1 - A4 - A3
Instance 9	0,497996	0,499677	0,434062	0,446821	A2 - A1 - A4 - A3
Instance 10	0,497996	0,499677	0,434062	0,446821	A2 - A1 - A4 - A3
Instance 11	0,492556	0,489969	0,425582	0,442957	A1 - A2 - A4 - A3
Instance 12	0,497619	0,500429	0,437678	0,447259	A2 - A1 - A4 - A3
Instance 13	0,4874	0,5104	0,4390	0,4571	A2 - A1 - A4 - A3
Instance 14	0,5011	0,4974	0,4316	0,4472	A1 - A2 - A4 - A3
Instance 15	0,4940	0,5066	0,4499	0,4506	A2 - A1 - A4 - A3
Instance 16	0,5007	0,5059	0,4296	0,4539	A2 - A1 - A4 - A3
Instance 17	0,4967	0,5129	0,4455	0,4565	A2 - A1 - A4 - A3
Instance 18	0,5015	0,5048	0,4477	0,4446	A2 - A1 - A3 - A4
Instnace 19	0,4930	0,5056	0,4488	0,4518	A2 - A1 - A4 - A3
Instance 20 (Equals)	0,4743	0,5267	0,4472	0,4692	A2 - A1 - A4 - A3

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