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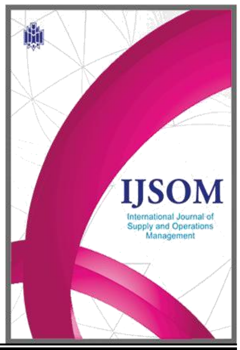


## A Multi-Criteria Decision Analysis Approach for Aligning IT and Supply Chain Strategies

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## Abstract

As a component of Information Technology Governance, Business-Information Technology Alignment (BITA) is more and more critical to the survival of enterprises. It ensures that Information Technology (IT) strategy is aligned and supports the business strategy, unleashing the potential of IT an avoiding loss of resources. The strategic alignment is a multi-criteria situation with a certain level of uncertainty for the Decision Makers (DM). There is a gap in the literature for IT alignment in a Supply Chain (SC) context with multi-criteria decision methods. This paper introduces a MCDM approach to align the IT and SC strategies. Furthermore, it provides a comparison between the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) and a hybrid Fuzzy Analytic Hierarchy Process (FAHP) FTOPSIS approach in aligning the IT strategy to the SC strategy. The approach introduced herein is illustrated for the case of a public pharmaceutical SC in Morocco. The results have shown the advantages of the fuzzy character of the methods at the strategic level and the differences between them for the prioritisation of the IT strategy.

**Keywords:** Multiple-criteria decision method (MCDM); IT alignment; Supply chain Management; Fuzzy; COBIT 2019; SCOR 12.0.

## 1. Introduction

IT Governance (ITG) is critical for enterprises in the way it continuously enforces the IT alignment with the business. Independently from the different views and definitions of ITG (Bouayad et al. 2017), IT alignment remains among the top priorities and challenges of Chief Information Officers (CIOs) and Chief Executive Officers (CEOs) (Coertze and Von Solms, 2014, Njanka et al., 2021). There are actual challenges and, in the same time, enablers of IT alignment that should be added to the 'classical' to-do list of IT, like, Digital transformation (Vial, 2019) to implement new business models, resilience of IT face to disruption like COVID-19 (He et al., 2020, Asadzadeh et al., 2020, Argüelles et al., 2021) or security of data.

IT alignment can be defined as 'the degree to which the IT mission, objectives, and plans support and are supported by the business mission, objectives, and plans' (Reich and benbasat, 1996). Since the 70's when the subject began to be exposed (McLean & Soden, 1977, Henderson and Sifonis, 1988), IT alignment continues to be a priority according to a survey of 11 years (Luftman et al., 2015). The advantage that the IT alignment can procure to the enterprise is better performance as empirically demonstrated (Chan et al., 2006, Chan and Reich, 2007). This performance can be materialized by an increase in revenues, agility, efficiency, reduction of cost, better risk management, and excellent customer service, development of new product and services and compliance to regulations. Control Objectives for Information and related Technology (COBIT) is a well-known ITG framework that aims to guide for the IT alignment in order to achieve the business value (Figure 1) (Haes and Grembergen, 2015, ISACA, 2018). It is used in different sectors like Education, Government and Finance (Steuperaert, 2017). This paper proposes to use the COBIT framework in a

Supply Chain context. COBIT treats also the strategic level in terms of processes or strategic objectives. The latter is detailed in section 3.

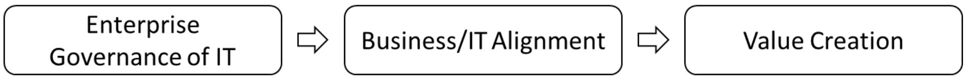


**Figure 1.** IT Governance versus Business/IT alignment (Haes and Grembergen, 2015)

In order to respond to a customer demand, all the parties should work together, from the suppliers to the retailers and customers (Chopra, S., 2019). Therefore, managing, synchronising and controlling all these parties defines the SC management. As SCOR is a SC standard that allows to describe the SC processes (Bolstoff, and R. Rosenbaum, 2011), SC Key performance indicators (Georgise et al., 2012) and practices, thus, it is interesting to pay a close attention to the relationship between SC and IT through SCOR and COBIT.

This paper proposes, on the one hand, a MCDM approach to align the IT and SC strategies. On the other hand, it provides a comparison between two approaches: (1) Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (FTOPSIS) that was elaborated by Chen in 1992 (Chen, and Hwang, 1992). (2) Hybrid Fuzzy Analytical Hierarchy Process (FAHP) with FTOPSIS. AHP was proposed in 1980 (Saaty, 1980) and FAHP in 1983 (Van Laarhoven and Pedrycz, 1983). To our knowledge, the combination of SCOR, COBIT with a MCDM is not found in the literature.

The objective of this paper is twofold: it first proposes an MCDM based approach to align between IT and SC strategies. Secondly, it compares the FTOPSIS results with a hybrid FAHP-FTOPSIS approach for the IT alignment applied in the context of the public sector pharmaceuticals SC in Morocco.

The rest of the paper is organised as follows: Section 2 presents a brief literature review of the IT alignment concept in general and in the SC context in particular. It also presents the COBIT and SCOR frameworks from which the criteria and alternatives come from, as well as, a presentation of the Fuzzy set theory, FAHP and FTOPSIS. Section 3 presents the methodology used to align the IT strategy to the SC strategy. Section 4 is the application of the two methods for a public pharmaceutical SC. Section 5 is the discussion of the results with the comparison of the two approaches concerning their alignment and use. Finally, in the last section, conclusions are drawn with propositions for future research.

## 2. Related work

The present section introduces to the concept of IT alignment, the SCOR SC framework, the COBIT ITG framework, as well as, a presentation of fuzzy theory, FAHP and FTOPSIS.

### 2.1. IT alignment

IT alignment represents, as defined by (Venkatraman and Henderson, 1993), the degree of fit and integration among business strategy, IT strategy, business infrastructure and IT infrastructure. These authors elaborated the Strategic Alignment Model (SAM). Based on the MIT research (Scott Morton 1991, Chan and Reich, 2007, Coltman et al., 2015), SAM is widely found in the literature for both researchers and practitioners (figure 2) which in turn, has been extended multiple times (Baets, 1992, Luftman et al, 1993, Maes et al., 2000, Avison et al., 2004) to compensate and complete some limitations in the model. SAM is a table of four cells that differentiates between External / Internal and Business / IT. Functional integration occurs between Business and IT while strategic fit designs the correspondence between External and Internal. The perfect alignment occurs when all these cells are aligned, which shows the difficulty of the task. Depending on the maturity level of the enterprise, there are cases when only two domains (bivariate) are needed to be aligned in order to reposition the enterprise in the market. But, the tendency is to align three domains (cross-domain alignment). Four dominants types of cross-domain alignment can occur:

- Strategy execution: when the business strategy is the driver and impacts the business and IT processes.
- Technology transformation: when the business strategy enables the change in the IT strategy and IT processes.
- Competitive potential: when the IT strategy influences the business strategy and processes.
- Service level: when the IT strategy impacts first the IT processes and the business processes.

SAM is a generic model whereas the IT alignment process is more sector and industry specific. There are some literature that treat this aspect. Table 1 shows a list of industries that have some references in IT alignment. Financial services, government or Education attracted more attention than others sectors. The maturity level of BITA depends on the industry, with the financial services organisations having the highest score and the public organisations the lowest (Silvius, 2007).

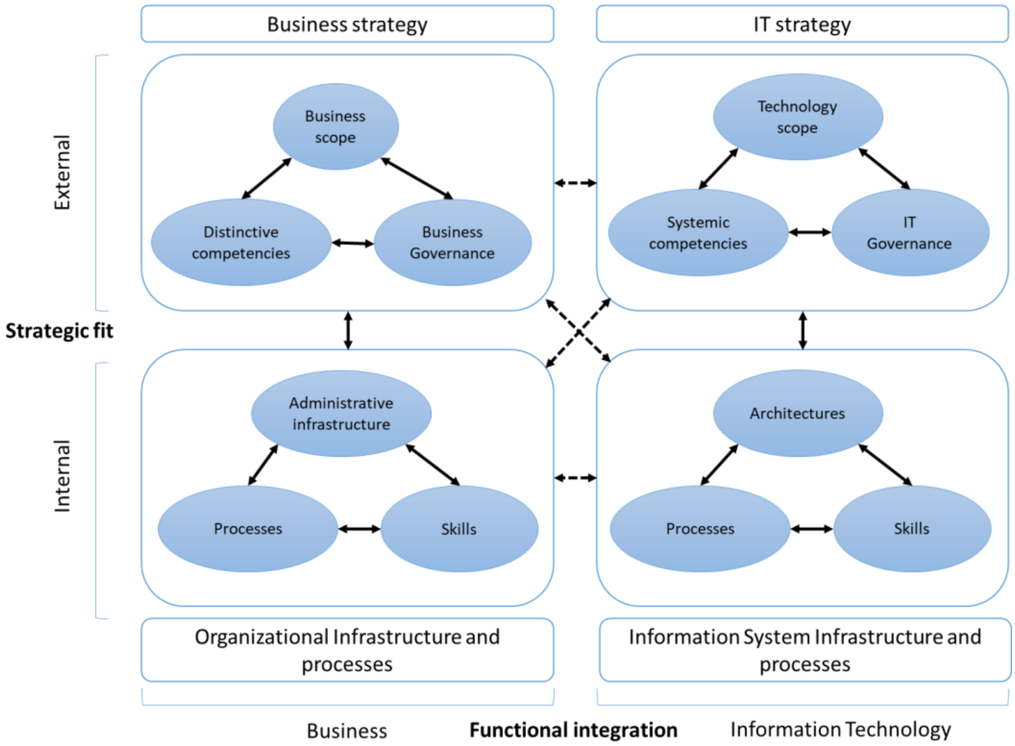


**Figure 2.** Strategic Alignment Model (Venkatraman and Henderson, 1993)

**Table 1.** IT alignment by industry

| **Industry/Sector** | **Work** | **Citation** |
|---|---|---|
| Government | Survey/interview. Issues and a framework to map the degree of IT/business strategy alignment | Weiss and Anderson, 2004 |
| | review | Rusu and Jonathan, 2017 |
| IT / Telecom | Survey | Weiss and Anderson, 2004 |
| | Proposition of a framework and a case study | Awasthi and Sangle, 2012 |
| Financial services | Survey | Weiss and Anderson, 2004 |
| | Review | Miller et al., 2014 |
| | Interviews. IT governance and alignment maturity | Safari and Jiang, 2018 |
| Defence | Survey | Weiss and Anderson, 2004 |
| Education | Survey | Weiss and Anderson, 2004 |
| | A model for business-IT alignment in Malaysian public universities | Seman and Salim, 2013 |
| | Critical review | Alghamdi and Sun, 2017 |
| Manufacturing | Survey | Weiss and Anderson, 2004 |
| Biopharmaceutical | Case study. IT Alignment with Balanced Scorecard | Hu and Huang, 2005 |
| Airline industry | empirical research framework with a commercial airline | Althonayan and Sharif, 2010 |
| Energy | Case study | Basili et al., 2013 |
| Health care | Survey/interviews. Assessment of IT alignment in heal care organizations | Iveroth et al., 2013 |
| | Assessment of IT alignment, case study | Rusu et al., 2008 |
| Hospitality industry | Interviews | Charoensuk et al., 2014 |
| Food industry | Feedback research technique and action research | Jaffar et al., 2007 |

For SC, many researches focus on bivariate alignment between IT systems or processes with business processes like Enterprise Resource Systems (ERP) (Schlichter and Kraemmergaard, 2010, Haddara and Zach, 2011, Ali and Miller, 2017). IT or digital technologies contribute to the performance SC in terms of an increase in efficiency and responsiveness (Qrunfleh and Tarafdar, 2014, Gunasekaran et al, 2017). However, few articles exist for strategic IT alignment in SC that is represented by the technology transformation perspective of SAM model. As this delicate equilibrium exercise can be described as a fuzzy challenge (Schütze, 2018) and there are many criteria that account in the process. The use of a multi-criteria method in a fuzzy environment can represent a way to facilitate the endeavour. The next sections will detail about multi-criteria methods and strategic criteria that can be used in the IT alignment process.

### 2.2 SCOR Framework

Supply Chain Operation Reference (SCOR) is SC framework maintained by the American Production and Inventory Control Society (APICS) (APICS, 2017). SCOR gives a common view of SC processes as well as key performance indicators, best practices and Technology. It then allows to model supply chains and to benchmark between them. Six major processes constitute the process model (Figure 3): (1) 'Plan' is a strategic domain that defines the requirements of the other domains in order to satisfy the demand. (2) 'Source' contains the processes that procure the goods or services needed as planned. (3) 'Make' processes create and add value to the good or service. (4) 'Deliver' processes manage the transport and the distribution and to the customer. (5) 'Return' allows the customer to return goods or the enterprise to return goods to the suppliers. (6) 'Enable' is a transverse domain that allows the alignment of the whole. It includes Financial, IT, Human resources, Facilities, Sales, Product design, Portfolio management and support.

SCOR is a multi-level configuration that is applied to processes and performance indicators. The SC performance is measured by two types of indicators: (1) The performance attributes that define a specific SC strategy which is a combination of Reliability, Responsiveness, Agility, Cost and Asset management. Section 3 details these indicators (2) The metrics, that measure a process or the overall SC. Level 1 metrics support the SC vision. Level 2 and level 3 metrics are diagnostics for the level 1 and level 2 metrics respectively.

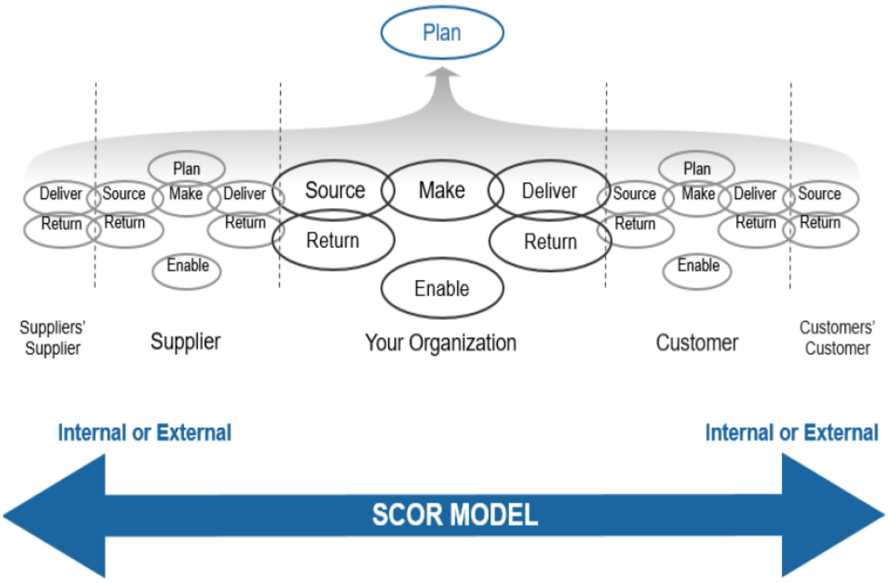


**Figure 3.** SCOR 12.0 Model (APICS, 2017)

### 2.3 COBIT Framework

Control Objectives for Information and related Technology (COBIT) appeared in 1996 as an IT audit framework. It is now a well-known ITG framework (Mangalaraj et al, 2014, Mulgund et al., 2019) that presents a holistic view of IT. It is maintained by Information Systems Audit and Control Association (ISACA, 2018). The last version, COBIT 2019, was released to adapt the framework to the changing environment and address some limitations of the previous version. New notions were introduced, especially, the notion of Focus Areas like Devops, Security, Risk,… Also the notion of Design Factors is added. These factors facilitate the framework to adapt to the specific enterprise context.
Five domains constitute the Core model (ISACA, 2018): (1) Evaluate, Direct and Monitor (EDM) domain addresses the governance objectives, while the following four domains address the Management objectives. (2) Align, Plan and Organize (APO) treats about the organisation as well as the strategy activities. (3) Build, Acquire and Implement (BAI) deals with the acquisition and implementation of IT. (4) Deliver, Service and Support (DSS) addresses the delivery and support of operational activities. (5) Monitor, Evaluate and Assess (MEA) monitors the performance and the conformance of IT with external and internal requirements (Figure 4).

For the core model, 3 processes were added, to reach 40 processes in global: 'Managed Data' in APO, 'Managed projects' in BAI and 'Managed Assurance' in MEA.

COBIT 2019 defines also alignment goals which represent the IT objectives and with which, it addresses the alignment of IT resources with the business ones. The IT goals are presented in the section 3.

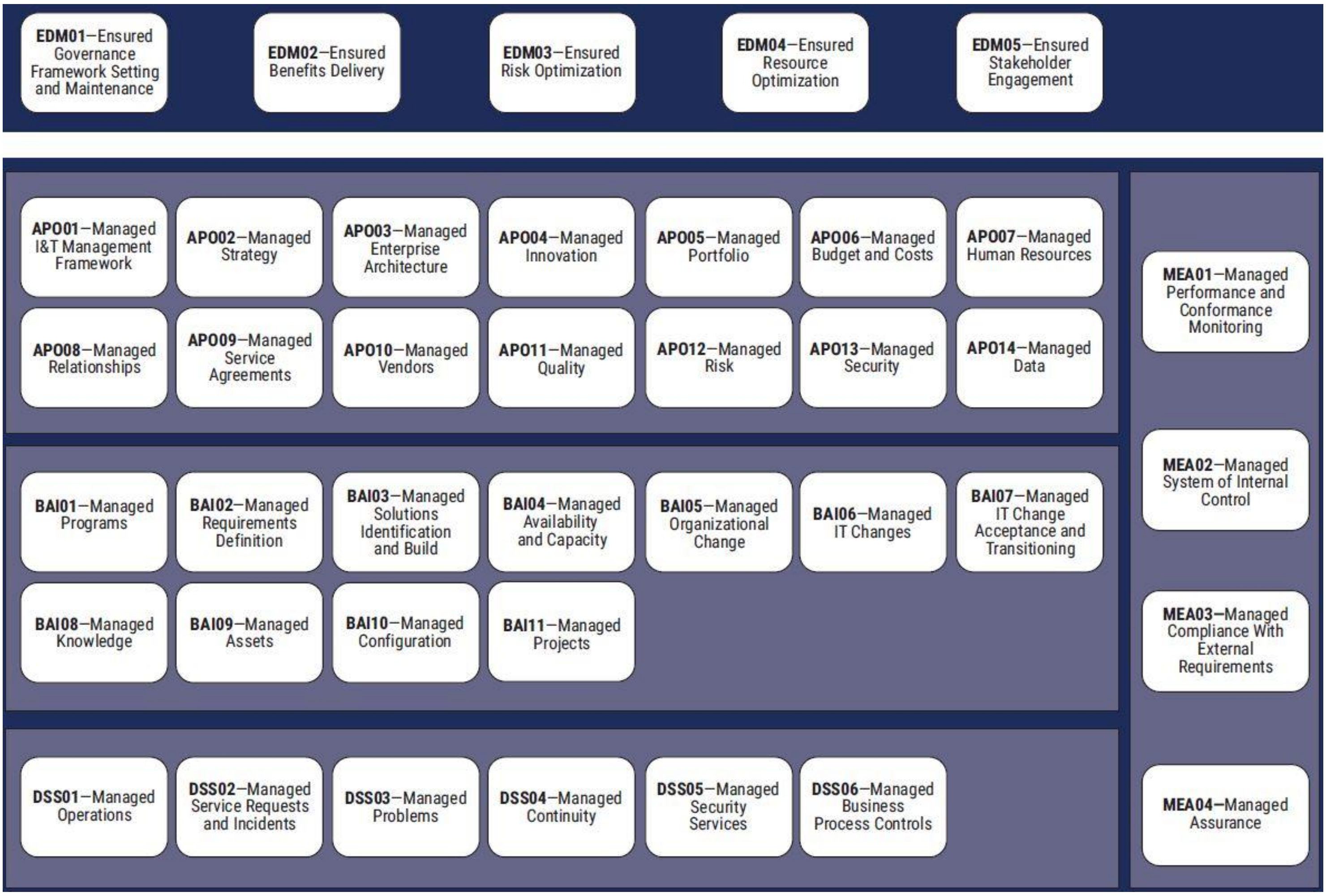


**Figure 4.** COBIT 2019 - 40 core Governance and management objectives (ISACA, 2018)

### 2.4 Fuzzy set theory

Fuzzy set theory was introduced by (Zadeh, 1965) and extends the crisp set theory in that it allows an element to partially belong to a fuzzy set. Fuzzy sets are very useful in modelling systems or situation with incomplete information (Tong, 1977, Kahraman et al., 2015, Blanco-Mesa et al., 2017). Fuzzy number is a fuzzy set that is convex and normal. There are multiple types of fuzzy numbers and triangular fuzzy numbers (TFN) are widespread. Figure 5 shows the graphical representation of a TFN $\tilde{x}\ (l, m, u)$ (with l, m, u real numbers and l < m < u) and Equation 1 the membership function that transforms an element of the fuzzy set to [0, 1].

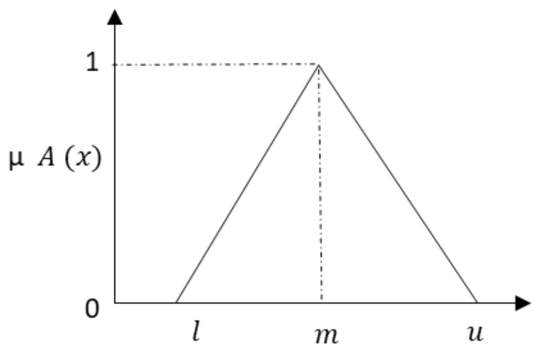


**Figure 5.** Graphical representation of a triangular fuzzy number

$$\mu_A(x) = \begin{cases} 0 & for\ x < l\ or\ x > u \\ \frac{x-l}{m-l} & for\ l \leq x \leq u \\ \frac{u-x}{u-m} & for\ m \leq x \leq u \end{cases} \tag{1}$$

To establish a strategy, DMs don't dispose of the complete information and generally they express their visions and evaluations in a linguistic form for the future mid-term or long term strategy. Linguistic variables have as values, words or sentences in natural or artificial language instead of numbers (Zadeh, 1975). To deal with uncertainty, MDCM techniques were combined with the fuzzy theory to form a new domain of fuzzy multi criteria decision making (FMCDM), which is more convenient to decisions in an uncertain environment (Kahraman et al., 2015, Blanco-Mesa et al., 2017). The following sections describe Fuzzy TOPSIS and Fuzzy AHP methods.

In order to use TFZ with MCDM, algebraic operations are needed. The following are the main operations for two positive TFN $\tilde{A}_1\ (l_1, m_1,\ u_1)$ and $\tilde{A}_2\ (l_2, m_2,\ u_2)$

$$\tilde{A}_1 + \tilde{A}_2 = (l_1 + l_2, m_1 + m_2,\ u_1 + u_2) \tag{2}$$

$$\tilde{A}_1 - \tilde{A}_2 = (l_1 - l_2, m_1 - m_2,\ u_1 - u_2) \tag{3}$$

$$\tilde{A}_1 * \tilde{A}_2 = (l_1 * l_2, m_1 * m_2,\ u_1 * u_2) \tag{4}$$

$$\tilde{A}_1 \div \tilde{A}_2 = (l_1 \div l_2, m_1 \div m_2,\ u_1 \div u_2) \tag{5}$$

$$\tilde{A}_1^{\ -1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right) \tag{6}$$

$$k * \tilde{A}_1 = (k * l_1, k * m_1,\ k * u_1) \qquad k\ \geq 0 \tag{7}$$

**2.5 Fuzzy TOPSIS and Fuzzy AHP**

A MCDM problem with n criteria $C_j$ ($C_1$, $C_2$, … , $C_n$) and m alternatives $A_i$ ($A_1$, $A_2$, …, $A_m$) can be modelled by the following decision matrix $\tilde{X}$ where $\tilde{x}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ is a fuzzy value that represents the evaluation of alternative Ai with respect to the criteria Cj according to the linguistic terms (Eq 8). The weight of each criteria determines its importance and is represented by the matrix $\widetilde{W}$ ($\widetilde{w}_1$,$\widetilde{w}_2$, … , $\widetilde{w}_n$).

$$\begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} & \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \dots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \dots & \tilde{x}_{2n} \\ \vdots & \vdots & \dots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \dots & \tilde{x}_{mn} \end{bmatrix} \end{array} \tag{8}$$

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was elaborated by (Hwang, and Yoon, 1981) and ranks among the most applied MCDM techniques (Zavadskas et al., 2016). It is very used for supply chain management decisions (Patil et al., 2020) and sustainability research (Zyoud, Fuchs-Hanusch, 2017). Its ease of use and facility of implementation contributes to its popularity. Fuzzy TOPSIS combines TOPSIS and fuzzy numbers in order to help DM decide about alternatives regarding multiple criteria (Chen and Hwang, 1992). FTOPSIS will be used as a stand-alone technique and also within the hybrid approach (section 3).

Another well-known MCDM is AHP that was developed in 1980 by (Saaty, 1980) as a method to help DM to choose among multiple alternatives regarding multiple criteria. It is a complete MCDM due to the fact that it computes both weights of criteria and alternatives priority (Liu et al., 2020). It transforms a problem into a hierarchy and, combined the ease of use, it has the ability to solve complex problems. These advantages make it widely spread (Emrouznejad and Marra, 2017) and in numerous sectors (HakimiAsl et al., 2016, Bouayad et al., 2018, Darko et al., 2019, Ersoy and Dogan, 2020).

To overcome the limitations of vague evaluations or incomplete information, the Fuzzy theory was combined with AHP to form Fuzzy AHP. The first application was in 1983 (Van Laarhoven and Pedrycz, 1983). Computation with fuzzy numbers are more complex that crisp values. To date many techniques are proposed for fuzzy operations. Based on the review of (Liu et al., 2020), the following techniques are used for Fuzzy AHP for the present work: (1) Type-1 fuzzy set with TFN are used for their ability describe the imprecision with a precise membership. (2) The aggregation of different DM is done with the max-min method with arithmetic mean. (3) The aggregation for fuzzy weights is done with the geometric mean which avoids the problem of rank reversal (Barzilai, 1997, Ishizaka and Labib, 2011, Aires and Ferreira, 2018, Liu et al., 2020). (4) The defuzzyfication is done with the centroid method. (5) The consistency check is done with the Saaty's method. As Fuzzy AHP is used to prioritize and determine the weighs of criteria, the details are presented in Section 3.

## 3. Suggested Methodology for IT alignment in a SC

This section presents the methodology used to align IT with the SC strategy and compare the results of the fuzzy methods. The approach, as illustrated in the (Figure 6), is structured in four phases.

**Phase 1:** The first phase is to determine the scope of the SC. The scope can be intra or intercompany, and depending on the complexity of the SC, it can include all or some stages of the SC.

**Phase 2:** The second phase allows to determine the MCDM criteria and alternatives. The criteria are represented by the SCOR performance attributes introduced in section 2.2, which describe the strategic characteristics of supply chain performance. These SC strategic objectives can be measured by the level 1 metrics and are as follows (APICS, 2017):

1. Reliability (RL) is an attribute that demonstrate the ability to perform the task as required.
2. Responsiveness (RS) is the attribute that describe the speed at which the tasks are performed.
3. Agility (AG) describe more the speed of change and adaptation to external constraints.
4. Cost (CO): represents the operational cost of the SC.
5. Asset Management (AM) is the attribute that measure the efficiency use of the SC.

For the IT perspective, as introduced in section 2.3, IT strategic objectives are represented by the COBIT alignment goals which ensure that all the IT efforts are aligned with the SC objectives. There are thirteen alignment goals and are as follows (ISACA, 2018):

1. IT compliance with regulations (AG01). This goal ensures that the IT of the organisation is compliant actual laws and regulations. The IT non-compliance issues are reported and managed.
2. Managed IT risk (AG02): this goal demonstrates that the enterprise put in place processes and controls to manage the IT risks.
3. Realized benefits from IT investments (AG03): this goal evaluates the value that comes out of the IT investments in terms of efficiency, productivity, velocity, … or it can also check the realisation of the service level agreements.
4. Quality of financial information (AG04): as the financial information is critical to take sound decisions, this goal follows the accuracy of financial key performance indicators.
5. Delivery of IT services in line with business requirements (AG05): the goal checks if the stakeholders or users are satisfied with IT service delivery
6. Agility to turn business requirements into operational solutions (AG06): This goal measures the responsiveness ability of IT to give a competitive advantage (time to market of IT services, IT initiatives, …)
7. Security of information, infrastructure and applications (AG07): this goal ensures that IT security incidents related to confidentiality, integrity or availability are managed.
8. Integrating applications and technology (AG08): the goal ensures that applications or infrastructure are not developed in silos
9. Delivery of programs as planned (AG09): programs are followed to see if they are delivered on time, budget and quality.
10. Quality of IT management information (AG10): as for financial information, IT management information should also be accurate.
11. IT compliance with internal policies (AG11): similar to the compliance with regulations, IT must be compliant with internal policies.
12. Competent staff (AG12): in order to have the synergy between the business and IT, both business and IT staff should be competent in their domain and role.
13. Business innovation (AG13): IT should be innovative and creative to bring the best of the IT to the business.

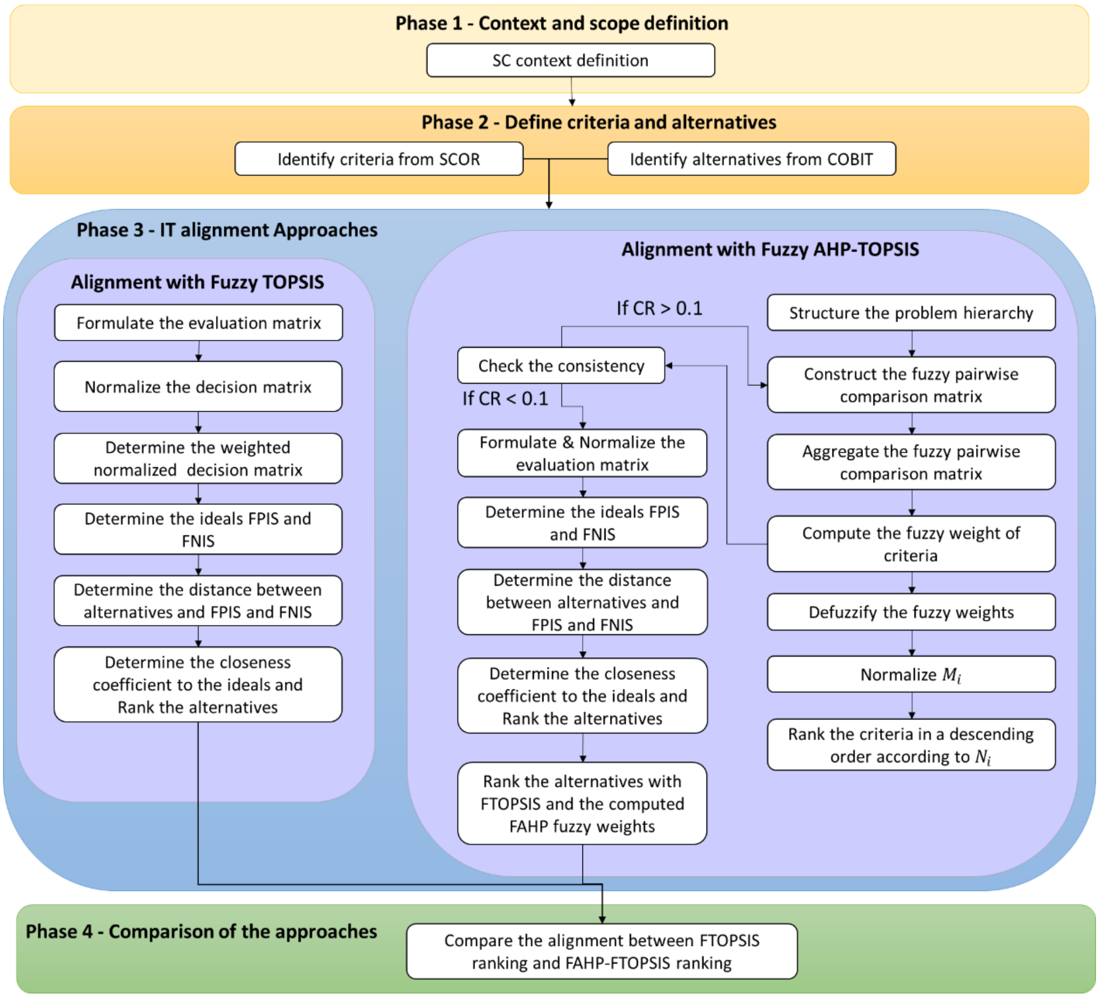


**Figure 6.** The proposed approach for the SC and IT alignment

**Phase 3:** The third phase consists of aligning IT and SC strategies with two approaches. The two methods FAHP and Fuzzy AHP-TOPSIS will prioritise the IT Goals according to the SC strategic criteria. The SC vision is materialised by the 5 SCOR performance attribute whereas, the IT strategy is represented by the 13 COBIT IT goals. The SC performance attributes are weighted according the enterprise vision. Then IT goals are evaluated according to each SC objectives. All the evaluations are done with linguistic terms in order to grasp the fuzziness of the DM view. The computation with the fuzzy TOPSIS and Fuzzy AHP-TOPSIS methods will give the prioritization of the IT goals. With this manner, the IT vision and strategy is aligned with the SC strategy. The implementation of the fuzzy model is developed by a worksheet and the linguistic terms can be adapted according each organization and situation.

The first approach which is Fuzzy TOPSIS approach consists of the six steps below:

Step 1 is the determination of $\tilde{x}_{ij}$ the evaluation of the alternative Ai with respect to the criteria Cj. When there are multiple Decision Makers (DM), $\tilde{x}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$ represents the fuzzy rating of the Decision Maker k concerning the alternative Ai with respect to the criteria Cj. The fuzzy rating $\tilde{x}_{ij}^k$ will be aggregated according the min-max method with arithmetic mean Eq. 9:

$$a_{ij} = \min_k(a_{ij}^k),\ b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ij}^k\,, c_{ij} = \max_k(c_{ij}^k) \tag{9}$$

$\tilde{w}_j^k = (w_{j1}^k, w_{j2}^k, w_{j3}^k)$ represents the weight of the criteria Cj evaluated by the k^th DM. The aggregation of the fuzzy weight $\tilde{w}_j^k$is done with the same manner that $\tilde{x}_{ij}^k$

$$w_{j1} = \min_k(w_{j1}^k),\ w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{j2}^k\,, w_{j3} = \max_k(w_{j3}^k) \tag{10}$$

Step 2 determines the normalized fuzzy decision matrix $\tilde{R} = (\tilde{r}_{ij})$. The computation depends on the type of the criteria. If it is a benefit criteria, higher is the linguistic scale, better is the rate. On the other hand, if it is a cost criteria, higher is the linguistic scale lower is the rate. The formulas are detailed as follows:

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \; with \; c_j^* = \max_i(c_{ij}) \; for\ the\ benefit\ criteria \tag{11}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \; with \; a_j^- = \min_i(a_{ij}) \; for\ the\ cost\ criteria \tag{12}$$

Step 3 computes the weighted normalized decision matrix $\tilde{V}$ by multiplying $\tilde{r}_{ij}$ by $\widetilde{w}_j$

$$\tilde{V} = \tilde{r}_{ij} * \widetilde{w}_j \tag{13}$$

Step 4 defines the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS), where $\tilde{v}_j = (v_{j1}, v_{j2}, v_{j3})$

$$A^* = [\tilde{v}_1^*, \tilde{v}_2^*, \dots, \tilde{v}_n^*] \; where \; \tilde{v}_j^* = \max_i v_{ij3} \;\; (FPIS) \tag{14}$$

$$A^- = [\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-] \; where \; \tilde{v}_j^{*-} = \min_i v_{ij1} \;\; (FNIS) \tag{15}$$

Step 5 computes the distance between alternatives and FPIS and FNIS

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), \;\; d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-) \tag{16}$$

The distance between two triangular fuzzy numbers$(\tilde{x}, \tilde{y})$, where $\tilde{x}\ (a_1, b_1, c_1)$ and $\tilde{y}\ (a_2, b_2, c_2)$ is calculated according the proposed vertex method (Chen, 2000):

$$d(\tilde{x}, \tilde{y}) = \sqrt{\frac{1}{3}((a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2)} \tag{17}$$

Step 6 determines the relative closeness coefficient to the ideals (FPIS, FNIS), and ranks the alternatives in descending order of the $CC_i$ index according to Eq. 11:

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-} \tag{18}$$

The second approach is a combination of FAHP to compute the fuzzy weight of criteria, and the FTOPSIS, to evaluate the alternatives according to the fuzzy criteria weights obtained with FAHP. The following steps (Liu et al., 2020) describe the computations for criteria weight prioritization:

Step 1: Structure the problem into a hierarchy. The first level is the goal. The second are the criteria and the last level shows the alternatives.

Step 2: Construct the fuzzy pairwise comparison matrix that evaluates the criteria regarding the goal. Let $\tilde{c}_{ij}^k = (l_{ij}^k, m_{ij}^k, u_{ij}^k)$ be the TFN that represents the relative importance, made by the k[th] DM, of criteria $C_i$ over $C_j$. The judgments can be synthetised according to the max-min method with arithmetic mean. The same formula of Fuzzy TOPSIS Eq. 9 is used here:

$$l_{ij} = \min_k(l_{ij}^k), \; m_{ij} = \frac{1}{k}\sum_{k=1}^{K} m_{ij}^k, u_{ij} = \max_k(u_{ij}^k) \tag{19}$$

Step 3: Aggregate the fuzzy pairwise comparison values with the geometric mean

$$\tilde{c}_i = \left(\prod_{j=1}^{n} \tilde{c}_{ij}\right)^{1/n} \tag{20}$$

Step 4: Compute the fuzzy weight of criteria.

$$\widetilde{w}_i = \frac{\tilde{c}_i}{\sum_{i=1}^{n} \tilde{c}_i} \tag{21}$$

Step 5: Defuzzify the fuzzy weights $\widetilde{w}_i$ with centroid method to obtain $M_i$, which is the most prevalent tool among the defuzzification methods (Sugeno, 1985; Lee, 1990, Ross, 2010, Liu et al., 2020). The general formula is as follows
Let $x^*$be the deffuzy number of $\tilde{x}$ that has the membership $\mu(x)$

$$x^* = \frac{\int \mu(x)xdx}{\int \mu(x)dx} \quad (22)$$

The formula is applied to TFN, the common formula is as follows (Sun, 2010)

$$M_i = \frac{l+m+u}{3} \quad (23)$$

Step 6: Normalise $M_i$ to obtain the normalised weighted criteria $N_i$

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (24)$$

Step 7: Rank the criteria in a descending order according to $N_i$.
Step 8: Check the consistency with the Saaty's method with crisp values.
Step 8a: First, the matrix is defuzzyfied with the following centroid method for TFN

$$\frac{l+2m+u}{4} \quad (25)$$

Step 8b: the Saaty's AHP method is used. Coherence Ratio $(CR)$ of the defuzzified matrix should be no more than 0.1.

$$CR = \frac{CI}{RI} \quad (26)$$

where (CI) represents the Consistency Index and (RI) is the Random Index from Table 2. CI is defined as:

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (27)$$

$\lambda_{\max}$ is computed as the average of the different ratios $(A_i\,.W)/W_i$:

$$\lambda = \frac{\sum_{i=1}^{n}(A_i\,.W)/W_i}{n} \quad (28)$$

**Table 2.** Scales of relative importance (RI) (Saaty, 1980)

| n | 2 | | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| RI | 0 | | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 |

If CR is below 0.1, which means that the weight calculations are coherent, we proceed with FTOPSIS to evaluate and rank the alternatives with the FAHP criteria fuzzy weights. Otherwise, the evaluation of criteria should be reviewed.
**Phase 4:** In the last phase, the results of IT-SC alignment of the different approaches are analysed. The rank of IT goals with FTOPSIS and FAHP-FTOPSIS approaches are compared and presented for business validation.

## 4. Application to the case of the public pharmaceuticals SC in Morocco

In this section, we give an illustration of our approach to the case of the Moroccan pharmaceutical SC. We also give a an in-depth presentation of the application of Fuzzy TOPSIS and Hybrid Fuzzy AHP-TOPSIS to the case study at hand, with the aim to determine and align the IT strategy with the SC strategy.

### 4.1. Phase 1: Context and scope definition for the case of Moroccan public pharmaceuticals supply chain

The Moroccan Ministry of Health (MMoH) has launched several transformation programs including the reform of the public sector pharmaceuticals SC, which is seen as a strong and strategic enabler to improve the citizens' health. Pharmaceutical products (PP) represented in 2013 approximately 40% of the ministry of Health's budget (Ministry of Health, 2014). The SC is complex, centralised, nation-wide as shown is the Figure 7. The pharmaceutical procurement division (PPD) is responsible for grouping needs, launching calls for tenders, and receiving, storing and distributing PP as well as supply monitoring. PP are transported from local pharmaceutical companies or international organisations to the central warehouse. All deliveries are done from this central point. It can deliver directly to the health centers or to regional and provincial warehouses before reaching the health centers (Moroccan Ministry of Health, 2014, Haial et al., 2016, Chorfi et al., 2019).

There are some challenges to overcome. Lead time delivery of PP to the regional warehouses or hospitals is highly variable and long at times (Mokrini et al. 2019). This puts the reliability as a priority. Also, due to the generalization of access to public healthcare services, it led to a high increase in pharmaceutical products' demand, which in return, led to an exponential and continual increase in the allocated budget in the recent years. The SC cost is also an important criterion to take into account for management decisions. It must respect the budget and the SC must run smoothly. Theses strategic SC objectives have an impact on IT and ITG. As IT is an enabler that can unleash great potential of the SC, the alignment between SC and IT strategic objectives is critical to have the durable outcome of IT.

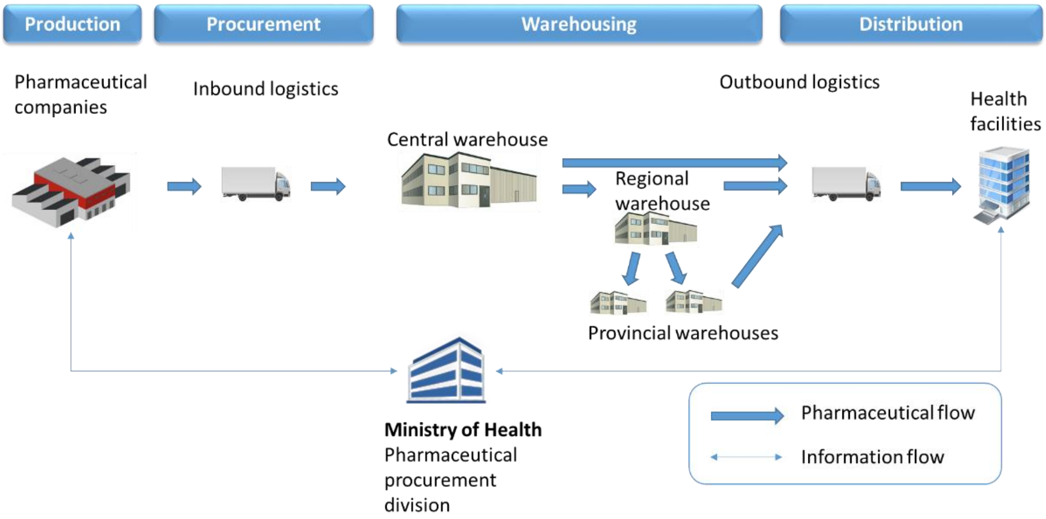


**Figure 7.** Moroccan public pharmaceutical supply chain (adapted from (Haial et al., 2016, Chorfi et al., 2019)

For phase 1 of our suggested approach, the SC context of the case study is limited to the intra-MMoH SC and does not include the pharmaceutical companies or other external stakeholders. It encompasses the procurement, warehousing at all stages and the distribution to health facilities nationwide.

### 4.2 Phase 2: decision criteria and alternatives generation

In phase 2, the criteria from SCOR 12.0 and alternatives from COBIT 2019 presented in section 3 are adopted. The intent is to prioritize and rank the IT strategic goals (AG01, AG02, …, AG13) that will enable the SC vision and strategy. Theses IT goals should, as explained in the previous paragraph, enhance the reliability and responsiveness while respecting the allocated budget of the MMoH. The improvement will also come from the mitigation of certain weaknesses of the public pharmaceutical SC (Tadlaoui et al. 2015) and the efficiency of the MMoH's information systems. Implementing a generalized Hospital Information System (HIS), training people of the SC for better inventory management in warehouses and hospitals can contribute to speed up delivery to patients. The evaluation is based on our assessment of the information available about the health strategy of the MMoH (Moroccan Ministry of Health, 2012, Moroccan Ministry of Health, 2018). It should be noted that the weights could be updated accordingly to take into account any changes in the Ministry of Health's IT strategy.

### 4.3 Phase 3: IT & SC alignment using MCDM methods:

The sections 4.3.1 and 4.3.2 present in detail the IT-SC alignment with the two approaches: FTOPSIS and hybrid FAHP-FTOPSIS.

#### 4.3.1 IT - SC alignment with Fuzzy TOPSIS

In this section, Fuzzy TOPSIS is used to align IT goals to the SC goals. The linguistic terms for our model come from the FTOPSIS author scales (Chen and Hwang, 1992) and are based on a 5-point scale. The evaluation of the decision matrix is done according the linguistic terms (Table 3):

**Table 3.** Linguistic terms for rating the alternatives

| Linguistic terms | Triangular Fuzzy Number |
|---|---|
| Very High (VH) | (7, 9, 10) |
| High (H) | (5, 7, 9) |
| Medium (M) | (3, 5, 7) |
| Low (L) | (1, 3, 5) |
| Very Low (VL) | (0, 1, 3) |

On the other hand, the evaluation of criteria weights is done according the linguistic terms in (Table 4):

**Table 4.** Linguistic terms for rating the weight of criteria

| **Linguistic terms** | **Triangular Fuzzy Number** |
|---|---|
| Very Important (VI) | (0.75, 1, 1) |
| Important (I) | (0.5, 0.75, 1) |
| Neutral (N) | (0.25, 0.5, 0.75) |
| Not Very Important (NVI) | (0, 0.25, 0.5) |
| Not at All Important (NAI) | (0, 0, 0.25) |

The obtained decision matrix which contains the criteria and alternative evaluations is as follows (Table 5):

**Table 5.** Decision matrix according to linguistic terms evaluations

| Criteria Weights | **I** | **N** | **N** | **VI** | **N** |
|---|---|---|---|---|---|
| SCOR Criteria | **RL** | **RS** | **AG** | **CO** | **AM** |
| IT Goals | | | | | |
| AG01 | H | L | L | H | M |
| AG02 | H | H | VH | H | M |
| AG03 | H | H | H | H | H |
| AG04 | M | M | M | VH | VH |
| AG05 | VH | VH | VH | H | H |
| AG06 | M | H | VH | H | M |
| AG07 | H | L | L | H | H |
| AG08 | VH | VH | VH | H | VH |
| AG09 | H | H | H | VH | VH |
| AG10 | VH | VH | H | H | M |
| AG11 | H | M | M | M | L |
| AG12 | H | M | M | VH | M |
| AG13 | M | M | M | H | H |

The linguistic terms were replaced by values according to Table 3 and 4. Then, the decision matrix was normalized and weighted according to Eq. 11 and Eq. 12 as described in section 3. Table 6 shows the results as follows:

**Table 6.** Normalized and weighted fuzzy decision matrix with the FPIS and FNIS

| **Fuzzy Weights** | 0.5 | 0.75 | 1 | 0.25 | 0.5 | 0.75 | 0.25 | 0.5 | 0.75 | 0.75 | 1 | 1 | 0.25 | 0.5 | 0.75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SCOR Criteria** | **RL** | | | **RS** | | | **AG** | | | **CO** | | | **AM** | | |
| **AG01** | 0.250 | 0.525 | 0.9 | 0.025 | 0.150 | 0.375 | 0.025 | 0.150 | 0.375 | 0.250 | 0.429 | 0.600 | 0.036 | 0.100 | 0.250 |
| **AG02** | 0.250 | 0.525 | 0.9 | 0.125 | 0.350 | 0.675 | 0.175 | 0.450 | 0.75 | 0.250 | 0.429 | 0.600 | 0.036 | 0.100 | 0.250 |
| **AG03** | 0.250 | 0.525 | 0.9 | 0.125 | 0.350 | 0.675 | 0.125 | 0.350 | 0.675 | 0.250 | 0.429 | 0.600 | 0.028 | 0.071 | 0.150 |
| **AG04** | 0.150 | 0.375 | 0.7 | 0.075 | 0.250 | 0.525 | 0.075 | 0.250 | 0.525 | 0.225 | 0.333 | 0.429 | 0.025 | 0.056 | 0.107 |
| **AG05** | 0.350 | 0.675 | 1 | 0.175 | 0.450 | 0.75 | 0.175 | 0.450 | 0.75 | 0.250 | 0.429 | 0.600 | 0.028 | 0.071 | 0.150 |
| **AG06** | 0.150 | 0.375 | 0.7 | 0.125 | 0.350 | 0.675 | 0.175 | 0.450 | 0.75 | 0.250 | 0.429 | 0.600 | 0.036 | 0.100 | 0.250 |
| **AG07** | 0.250 | 0.525 | 0.9 | 0.025 | 0.150 | 0.375 | 0.025 | 0.150 | 0.375 | 0.250 | 0.429 | 0.600 | 0.028 | 0.071 | 0.150 |
| **AG08** | 0.350 | 0.675 | 1 | 0.175 | 0.450 | 0.75 | 0.175 | 0.450 | 0.75 | 0.250 | 0.429 | 0.600 | 0.025 | 0.056 | 0.107 |
| **AG09** | 0.250 | 0.525 | 0.9 | 0.125 | 0.350 | 0.675 | 0.125 | 0.350 | 0.675 | 0.225 | 0.333 | 0.429 | 0.025 | 0.056 | 0.107 |
| **AG10** | 0.350 | 0.675 | 1 | 0.175 | 0.450 | 0.75 | 0.125 | 0.350 | 0.675 | 0.250 | 0.429 | 0.600 | 0.036 | 0.100 | 0.250 |
| **AG11** | 0.250 | 0.525 | 0.9 | 0.075 | 0.250 | 0.525 | 0.075 | 0.250 | 0.525 | 0.321 | 0.600 | 1 | 0.050 | 0.167 | 0.750 |
| **AG12** | 0.250 | 0.525 | 0.9 | 0.075 | 0.250 | 0.525 | 0.075 | 0.250 | 0.525 | 0.225 | 0.333 | 0.429 | 0.036 | 0.100 | 0.250 |
| **AG13** | 0.150 | 0.375 | 0.7 | 0.075 | 0.250 | 0.525 | 0.075 | 0.250 | 0.525 | 0.250 | 0.429 | 0.600 | 0.028 | 0.071 | 0.150 |
| **FPIS** | **0.350** | **0.675** | **1** | **0.175** | **0.450** | **0.75** | **0.175** | **0.450** | **0.75** | **0.225** | **0.333** | **0.429** | **0.025** | **0.056** | **0.107** |
| **FNIS** | **0.150** | **0.375** | **0.700** | **0.025** | **0.150** | **0.375** | **0.025** | **0.150** | **0.375** | **0.321** | **0.600** | **1.000** | **0.050** | **0.167** | **0.750** |

The distance between each alternatives and the FPIS and FNIS (d* and d-) are calculated with Eq.16 and Eq. 17 and are as follows (Table 7 and Table 8):

**Table 7.** Distance d* between alternatives and FPIS

| | RL | RS | AG | CO | AM | d* |
|---|---|---|---|---|---|---|
| AG01 | 0.119 | 0.290 | 0.290 | 0.114 | 0.087 | 0.901 |
| AG02 | 0.119 | 0.078 | 0.000 | 0.114 | 0.087 | 0.397 |
| AG03 | 0.119 | 0.078 | 0.078 | 0.114 | 0.026 | 0.415 |
| AG04 | 0.271 | 0.183 | 0.183 | 0.000 | 0.000 | 0.637 |
| AG05 | 0.000 | 0.000 | 0.000 | 0.114 | 0.026 | 0.141 |
| AG06 | 0.271 | 0.078 | 0.000 | 0.114 | 0.087 | 0.549 |
| AG07 | 0.119 | 0.290 | 0.290 | 0.114 | 0.026 | 0.841 |
| AG08 | 0.000 | 0.000 | 0.000 | 0.114 | 0.000 | 0.114 |
| AG09 | 0.119 | 0.078 | 0.078 | 0.000 | 0.000 | 0.274 |
| AG10 | 0.000 | 0.000 | 0.078 | 0.114 | 0.087 | 0.278 |
| AG11 | 0.119 | 0.183 | 0.183 | 0.368 | 0.377 | 1.231 |
| AG12 | 0.119 | 0.183 | 0.183 | 0.000 | 0.087 | 0.572 |
| AG13 | 0.271 | 0.183 | 0.183 | 0.114 | 0.026 | 0.778 |

**Table 8.** Distance d- between alternatives and FNIS

| | RL | RS | AG | CO | AM | d- |
|---|---|---|---|---|---|---|
| AG01 | 0.155 | 0.000 | 0.000 | 0.255 | 0.291 | 0.701 |
| AG02 | 0.155 | 0.216 | 0.290 | 0.255 | 0.291 | 1.208 |
| AG03 | 0.155 | 0.216 | 0.216 | 0.255 | 0.351 | 1.193 |
| AG04 | 0.000 | 0.108 | 0.108 | 0.368 | 0.377 | 0.961 |
| AG05 | 0.271 | 0.290 | 0.290 | 0.255 | 0.351 | 1.457 |
| AG06 | 0.000 | 0.216 | 0.290 | 0.255 | 0.291 | 1.052 |
| AG07 | 0.155 | 0.000 | 0.000 | 0.255 | 0.351 | 0.761 |
| AG08 | 0.271 | 0.290 | 0.290 | 0.255 | 0.377 | 1.483 |
| AG09 | 0.155 | 0.216 | 0.216 | 0.368 | 0.377 | 1.333 |
| AG10 | 0.271 | 0.290 | 0.216 | 0.255 | 0.291 | 1.323 |
| AG11 | 0.155 | 0.108 | 0.108 | 0.000 | 0.000 | 0.371 |
| AG12 | 0.155 | 0.108 | 0.108 | 0.368 | 0.291 | 1.031 |
| AG13 | 0.000 | 0.108 | 0.108 | 0.255 | 0.351 | 0.822 |

Finally, the computation of the relative closeness coefficient (CCi) with Eq. 18 to the ideals and the ranking of alternatives in descending order of the CCi gives the priority of each IT goal according to the SCOR performance attribute (Table 9).

The ranking shows that AG08, AG05 and AG09 are the top 3 IT goals that define the IT strategy:

- ✓ AG08 goal is to integrate SC applications and Technology.
- ✓ AG05 goal is to align IT services with SC requirements
- ✓ AG09 goal is to Deliver programs as planned

The AG08 goal is to have an information system that integrates all hospitals, health centres, warehouses, and the MMoH head office. It is yet, the core of the transformation and digitalization of the pharmaceutical SC. The AG05 goal is to support the user of the IT service and the level of service that should be of high availability nationwide. Finally, the AG09 is the execution part in building the integrated system or making the IT services available to users or other systems. Quality, Security and Conformance are also important goals to take into account. According to the classification, it would be in the second phase of the IT strategy implementation.

**Table 9.** Ranking of it goals according to the closeness coefficient

| CCi | Rank | IT Goals |
|---|---|---|
| 0.9285 | 1 | AG08 |
| 0.9120 | 2 | AG05 |
| 0.8292 | 3 | AG09 |
| 0.8261 | 4 | AG10 |
| 0.7524 | 5 | AG02 |
| 0.7419 | 6 | AG03 |
| 0.6571 | 7 | AG06 |
| 0.6432 | 8 | AG12 |
| 0.6014 | 9 | AG04 |
| 0.5137 | 10 | AG13 |
| 0.4752 | 11 | AG07 |
| 0.4378 | 12 | AG01 |
| 0.2319 | 13 | AG11 |

### 4.3.2 IT -SC alignment with an Hybrid approach with Fuzzy AHP and Fuzzy TOPSIS

The first part of the hybrid approach is to compute the weights of criteria with Fuzzy AHP. The coherence ratio CR is verified that it is less than 0.1. Then Fuzzy TOPSIS is used to rank the alternatives taking into account the fuzzy weight from FAHP. The hierarchy of the problem is as follows (Figure 8). The goal is to align IT strategy with SC strategy. The criteria are the SCOR Performance attribute. And the alternatives are the COBIT IT Alignment Goals.

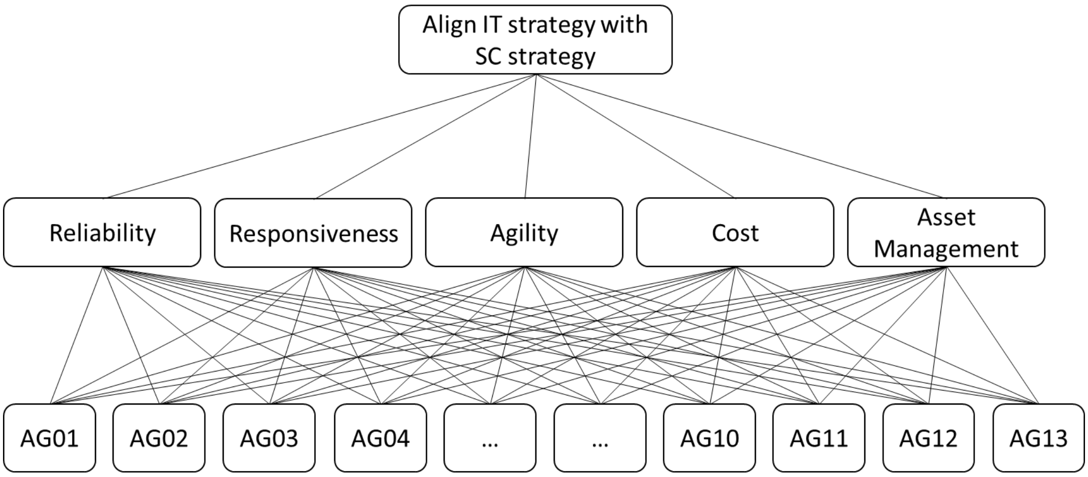


**Figure 8.** Structure of the problem with a hierarchy

The linguistic terms used for pairwise comparison of criteria are presented in Table 10. It's a 9 level scale that commonly adopted according the review of (Liu et al., 2020) for TFN. The extreme values for the example are (1,1,1) and (9,9,9).

**Table 10.** Linguistic term for rating the weight of criteria

| Linguistic terms for rating the weight of criteria | | Triangular Fuzzy Number |
|---|---|---|
| Extremely Strong Importance | **ESI** | **(9,9,9)** |
| Very Strong to Extremely Strong Importance | VSESI | (7,8,9) |
| Very Strong Importance | **VSI** | **(6,7,8)** |
| Strong to Very Strong Importance | SVSI | (5,6,7) |
| Strong Importance | **SI** | **(4,5,6)** |
| Moderate to Strong Importance | MSI | (3,4,5) |
| Moderate Importance | **MI** | **(2,3,4)** |
| Equally to Moderate Importance | EMI | (1,2,3) |
| Equally Importance | **EI** | **(1,1,1)** |

The evaluation of the criteria pairwise comparison regarding the goal of aligning IT goals to SC goals with linguistic terms is presented in the following table (Table 11):

**Table 11.** Criteria pairwise comparison with linguistic terms

| ESI (9,9,9) | VSI (6,7,8) | SI (4,5,6) | MI (2,3,4) | Criteria | EI (1,1,1) | Criteria | MI (2,3,4) | SI (4,5,6) | VSI (6,7,8) | ESI (9,9,9) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | C1 | | C2 | ✓ | | | |
| | | | | C1 | | C3 | ✓ | | | |
| | | | ✓ | C1 | | C4 | | | | |
| | | | | C1 | | C5 | ✓ | | | |
| | | | | C2 | | C3 | ✓ | | | |
| | | ✓ | | C2 | | C4 | | | | |
| | | | ✓ | C2 | | C5 | | | | |
| | ✓ | | | C3 | | C4 | | | | |
| | | | ✓ | C3 | | C5 | | | | |
| | | | | C4 | | C5 | ✓ | | | |

The linguistic terms of the evaluations are replaced by their correspondent values from table 10. The criteria pairwise comparison is presented in Table 12:

**Table 12.** Criteria pairwise comparison with values

| **Criteria** | C1 | | | C2 | | | C3 | | | C4 | | | C5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 | 1 | 1 | 1 | 2 | 3 | 4 | 2 | 3 | 4 | 1/4 | 1/3 | 1/2 | 2 | 3 | 4 |
| C2 | 1/4 | 1/3 | 1/2 | 1 | 1 | 1 | 2 | 3 | 4 | 1/6 | 1/5 | 1/4 | 1/4 | 1/3 | 1/2 |
| C3 | 1/4 | 1/3 | 1/2 | 1/4 | 1/3 | 1/2 | 1 | 1 | 1 | 1/8 | 1/7 | 1/6 | 1/4 | 1/3 | 1/2 |
| C4 | 2 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 1 | 1 | 1 | 2 | 3 | 4 |
| C5 | 1/4 | 1/3 | 1/2 | 2 | 3 | 4 | 2 | 3 | 4 | 1/4 | 1/3 | 1/2 | 1 | 1 | 1 |

The aggregate of the fuzzy pairwise comparison values is computed with the geometric mean (Eq. 20) as shown in (Table 13):

**Table 13.** Aggregation of the fuzzy pairwise comparison

| **Criteria** | $\tilde{c}_i$ | | |
|---|---|---|---|
| C1 | 1.149 | 1.552 | 2.000 |
| C2 | 0.461 | 0.582 | 0.758 |
| C3 | 0.287 | 0.351 | 0.461 |
| C4 | 2.491 | 3.160 | 3.776 |
| C5 | 0.758 | 1.000 | 1.320 |
| **Total** | 5.146 | 6.644 | 8.315 |
| **Total** $^{-1}$ | 0.120 | 0.151 | 0.194 |

Then, the fuzzy weight of criteria are determined with Eq. 21 as shown in table 14:

**Table 14.** Fuzzy weight of criteria

| **Criteria** | $\tilde{w}_i$ | | |
|---|---|---|---|
| C1 | 0.138 | 0.234 | 0.389 |
| C2 | 0.055 | 0.088 | 0.147 |
| C3 | 0.035 | 0.053 | 0.090 |
| C4 | 0.300 | 0.476 | 0.734 |
| C5 | 0.091 | 0.151 | 0.256 |

Finally, the normalized weighed criteria with the ranking are deduced with Eq. 23 and Eq. 24 (Table 15):

**Table 15.** Normalised weighted criteria and ranking with FAHP

| Criteria | Mi | Ni | Rank |
|---|---|---|---|
| C1 | 0.253 | **0.235** | **2** |
| C2 | 0.097 | **0.090** | **4** |
| C3 | 0.059 | **0.055** | **5** |
| C4 | 0.503 | **0.467** | **1** |
| C5 | 0.166 | **0.154** | **3** |

The check for consistency is essential to validate the results obtained in table 15. The fuzzy evaluation matrix (Table 12) is deffuzified with the centroid method (Eq. 25) and the results are as follows (Table 16):

**Table 16.** Defuzzification with centroid method (l+2m+u)/4

| Criteria | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| C1 | 1 | 3 | 3 | 1/3 | 3 |
| C2 | 1/3 | 1 | 3 | 1/5 | 1/3 |
| C3 | 1/3 | 1/3 | 1 | 1/7 | 1/3 |
| C4 | 3 | 5 | 7 | 1 | 3 |
| C5 | 1/3 | 3 | 3 | 1/3 | 1 |

The rest follows the classical AHP steps with crisp values, with normalising the matrix and computing the weight of each criteria with the geometric mean (Table 17):

**Table 17.** Normalized matrix of criteria to check the consistency of FAHP evaluation

| Criteria | C1 | C2 | C3 | C4 | C5 | Weight |
|---|---|---|---|---|---|---|
| C1 | 0.198 | 0.243 | 0.176 | 0.172 | 0.389 | 0.2243 |
| C2 | 0.070 | 0.081 | 0.176 | 0.099 | 0.046 | 0.0855 |
| C3 | 0.070 | 0.029 | 0.059 | 0.070 | 0.046 | 0.0520 |
| C4 | 0.593 | 0.405 | 0.412 | 0.486 | 0.389 | 0.4511 |
| C5 | 0.070 | 0.243 | 0.176 | 0.172 | 0.130 | 0.1463 |

The Consistency index is obtained with Eq. 27 gives a value of 0.0989 and the Coherence ratio computed with Eq. 26 gives 0.0883 which is inferior to 0.1. The ranking of criteria and the Fuzzy weight of criteria can be considered as acceptable.

The fuzzy weights obtained in table 14 replaced the fuzzy weights in Table 6 and are used with the fuzzy TOPSIS evaluation (Table 18).

**Table 18.** Weighted normalized fuzzy matrix for the FAHP-FTOPSIS approach

| **Fuzzy Weights** | 0.138 | 0.234 | 0.389 | 0.055 | 0.088 | 0.147 | 0.035 | 0.053 | 0.090 | 0.300 | 0.476 | 0.734 | 0.091 | 0.151 | 0.256 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | RL | | | RS | | | Agility | | | CO | | | AM | | |
| AG01 | 0.069 | 0.163 | 0.350 | 0.006 | 0.026 | 0.074 | 0.003 | 0.016 | 0.045 | 0.100 | 0.204 | 0.440 | 0.013 | 0.030 | 0.085 |
| AG02 | 0.069 | 0.163 | 0.350 | 0.028 | 0.061 | 0.133 | 0.024 | 0.047 | 0.090 | 0.100 | 0.204 | 0.440 | 0.013 | 0.030 | 0.085 |
| AG03 | 0.069 | 0.163 | 0.350 | 0.028 | 0.061 | 0.133 | 0.017 | 0.037 | 0.081 | 0.100 | 0.204 | 0.440 | 0.010 | 0.022 | 0.051 |
| AG04 | 0.041 | 0.117 | 0.272 | 0.017 | 0.044 | 0.103 | 0.010 | 0.026 | 0.063 | 0.090 | 0.159 | 0.314 | 0.009 | 0.017 | 0.037 |
| AG05 | 0.097 | 0.210 | 0.389 | 0.039 | 0.079 | 0.147 | 0.024 | 0.047 | 0.090 | 0.100 | 0.204 | 0.440 | 0.010 | 0.022 | 0.051 |
| AG06 | 0.041 | 0.117 | 0.272 | 0.028 | 0.061 | 0.133 | 0.024 | 0.047 | 0.090 | 0.100 | 0.204 | 0.440 | 0.013 | 0.030 | 0.085 |
| AG07 | 0.069 | 0.163 | 0.350 | 0.006 | 0.026 | 0.074 | 0.003 | 0.016 | 0.045 | 0.100 | 0.204 | 0.440 | 0.010 | 0.022 | 0.051 |
| AG08 | 0.097 | 0.210 | 0.389 | 0.039 | 0.079 | 0.147 | 0.024 | 0.047 | 0.090 | 0.100 | 0.204 | 0.440 | 0.009 | 0.017 | 0.037 |
| AG09 | 0.069 | 0.163 | 0.350 | 0.028 | 0.061 | 0.133 | 0.017 | 0.037 | 0.081 | 0.090 | 0.159 | 0.314 | 0.009 | 0.017 | 0.037 |
| AG10 | 0.097 | 0.210 | 0.389 | 0.039 | 0.079 | 0.147 | 0.017 | 0.037 | 0.081 | 0.100 | 0.204 | 0.440 | 0.013 | 0.030 | 0.085 |
| AG11 | 0.069 | 0.163 | 0.350 | 0.017 | 0.044 | 0.103 | 0.010 | 0.026 | 0.063 | 0.128 | 0.285 | 0.734 | 0.018 | 0.050 | 0.256 |

**Table 18.** Continued

| **Fuzzy Weights** | 0.138 | 0.234 | 0.389 | 0.055 | 0.088 | 0.147 | 0.035 | 0.053 | 0.090 | 0.300 | 0.476 | 0.734 | 0.091 | 0.151 | 0.256 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | RL | | | RS | | | Agility | | | CO | | | AM | | |
| AG12 | 0.069 | 0.163 | 0.350 | 0.017 | 0.044 | 0.103 | 0.010 | 0.026 | 0.063 | 0.090 | 0.159 | 0.314 | 0.013 | 0.030 | 0.085 |
| AG13 | 0.041 | 0.117 | 0.272 | 0.017 | 0.044 | 0.103 | 0.010 | 0.026 | 0.063 | 0.100 | 0.204 | 0.440 | 0.010 | 0.022 | 0.051 |
| **FPIS** | **0.097** | **0.210** | **0.389** | **0.039** | **0.079** | **0.147** | **0.024** | **0.047** | **0.090** | **0.090** | **0.159** | **0.314** | **0.009** | **0.017** | **0.037** |
| **FNIS** | **0.041** | **0.117** | **0.272** | **0.006** | **0.026** | **0.074** | **0.003** | **0.016** | **0.045** | **0.128** | **0.285** | **0.734** | **0.018** | **0.050** | **0.256** |

The computation of the distance between alternatives (IT goals) and the ideals FPIS and FNIS are done with Eq. 16, Eq. 17 and are presented in table 19 and 20.

**Table 19.** Distance of IT Goals to FPIS for the FAHP-FTOPSIS approach

| | **RL** | **RS** | **AG** | **CO** | **AM** | **di*** |
|---|---|---|---|---|---|---|
| **AG01** | 0.039 | 0.056 | 0.034 | 0.077 | 0.029 | 0.235 |
| **AG02** | 0.039 | 0.015 | 0.000 | 0.077 | 0.029 | 0.160 |
| **AG03** | 0.039 | 0.015 | 0.009 | 0.077 | 0.009 | 0.148 |
| **AG04** | 0.092 | 0.035 | 0.021 | 0.000 | 0.000 | 0.148 |
| **AG05** | 0.000 | 0.000 | 0.000 | 0.077 | 0.009 | 0.086 |
| **AG06** | 0.092 | 0.015 | 0.000 | 0.077 | 0.029 | 0.213 |
| **AG07** | 0.039 | 0.056 | 0.034 | 0.077 | 0.009 | 0.214 |
| **AG08** | 0.000 | 0.000 | 0.000 | 0.077 | 0.000 | 0.077 |
| **AG09** | 0.039 | 0.015 | 0.009 | 0.000 | 0.000 | 0.062 |
| **AG10** | 0.000 | 0.000 | 0.009 | 0.077 | 0.029 | 0.116 |
| **AG11** | 0.039 | 0.035 | 0.021 | 0.254 | 0.128 | 0.477 |
| **AG12** | 0.039 | 0.035 | 0.021 | 0.000 | 0.029 | 0.124 |
| **AG13** | 0.092 | 0.035 | 0.021 | 0.077 | 0.009 | 0.235 |

**Table 20.** Distance of IT goals to FNIS for the FAHP-FTOPSIS approach

| | **RL** | **RS** | **AG** | **CO** | **AM** | **di-** |
|---|---|---|---|---|---|---|
| **AG01** | 0.055 | 0.000 | 0.000 | 0.177 | 0.099 | 0.331 |
| **AG02** | 0.055 | 0.042 | 0.034 | 0.177 | 0.099 | 0.406 |
| **AG03** | 0.055 | 0.042 | 0.025 | 0.177 | 0.120 | 0.418 |
| **AG04** | 0.000 | 0.021 | 0.013 | 0.254 | 0.128 | 0.416 |
| **AG05** | 0.092 | 0.056 | 0.034 | 0.177 | 0.120 | 0.478 |
| **AG06** | 0.000 | 0.042 | 0.034 | 0.177 | 0.099 | 0.352 |
| **AG07** | 0.055 | 0.000 | 0.000 | 0.177 | 0.120 | 0.351 |
| **AG08** | 0.092 | 0.056 | 0.034 | 0.177 | 0.128 | 0.487 |
| **AG09** | 0.055 | 0.042 | 0.025 | 0.254 | 0.128 | 0.504 |
| **AG10** | 0.092 | 0.056 | 0.025 | 0.177 | 0.099 | 0.449 |
| **AG11** | 0.055 | 0.021 | 0.013 | 0.000 | 0.000 | 0.088 |
| **AG12** | 0.055 | 0.021 | 0.013 | 0.254 | 0.099 | 0.441 |
| **AG13** | 0.000 | 0.021 | 0.013 | 0.177 | 0.120 | 0.330 |

The computation of CCi is done with Eq. 18. The result of the hybrid approach is then presented in table 21.

**Table 21.** Ranking according CCi for the FAHP-FTOPSIS approach

| CCi | Rank | IT Goals |
|---|---|---|
| 0.8902 | 1 | AG09 |
| 0.8627 | 2 | AG08 |
| 0.8470 | 3 | AG05 |
| 0.7952 | 4 | AG10 |
| 0.7806 | 5 | AG12 |
| 0.7379 | 6 | AG03 |
| 0.7372 | 7 | AG04 |
| 0.7175 | 8 | AG02 |
| 0.6223 | 9 | AG06 |
| 0.6209 | 10 | AG07 |
| 0.5849 | 11 | AG01 |
| 0.5844 | 12 | AG13 |
| 0.1560 | 13 | AG11 |

### 4.4 Phase 4: Results comparison and analysis

This section presents and compares the results of our approach as detailed below:
The results of both FTOPSIS and hybrid fuzzy AHP-TOPSIS alignment are presented in Table 22. There are 3 IT goals that have the same raking (AG10, AG03, AG11), the other goals see their ranking change slightly, generally by one rank.

**Table 22.** Comparison of FTOPSIS and hybrid fuzzy AHP-TOPSIS alignment

| | | | FTOPSIS | | FAHP-TOPSIS | |
|---|---|---|---|---|---|---|
| **IT goals** | **Description of IT Goals** | **CCi** | **Rank** | **CCi** | **Rank** | **Group** |
| AG08 | Integration of applications and technology | 0.9285 | 1 | 0.8627 | 2 | Group 1 |
| AG05 | Delivery of IT services as requested | 0.9120 | 2 | 0.8470 | 3 | |
| AG09 | Delivery of programs as planned | 0.8292 | 3 | 0.8902 | 1 | |
| AG10 | Reliability of IT management information | 0.8261 | 4 | 0.7952 | 4 | |
| AG02 | IT risk management | 0.7524 | 5 | 0.7175 | 8 | Group 2 |
| AG03 | Return of investment of IT | 0.7419 | 6 | 0.7379 | 6 | |
| AG06 | Agility implement new operational solutions | 0.6571 | 7 | 0.6223 | 9 | |
| AG12 | Competent human resources in IT and Business | 0.6432 | 8 | 0.7806 | 5 | |
| AG04 | Reliability technology-related financial information | 0.6014 | 9 | 0.7372 | 7 | |
| AG13 | Knowledge management and innovation | 0.5137 | 10 | 0.5844 | 12 | Group 3 |
| AG07 | IT security | 0.4752 | 11 | 0.6209 | 10 | |
| AG01 | Compliance of IT with external regulations and laws | 0.4378 | 12 | 0.5849 | 11 | |
| AG11 | Compliance of IT with internal policies | 0.2319 | 13 | 0.1560 | 13 | |

As the context is at a strategic level, it is interesting to distinguish homogenous groups of priorities using the similitudes of both FAHP and Hybrid Fuzzy AHP-TOPSIS. Three groups can be defined according to the ranking (Figure 9):

- ✓ Group 1 contains 4 IT goals (AG08, AG05, AG09, AG10)
- ✓ Group 2 contains 5 IT goals (AG02, AG03, AG06, AG12, AG04)
- ✓ Group 3 has 4 IT goals (AG13, AG07, AG01, AG11)

The fact that there are similarities shows that both methods give the same trend for the priority of IT goals. Which gives more trust in the ranking. The group 1 would define the phase 1 for the strategy for IT, by focusing on integrating systems (AG08) and delivering IT services (AG05) with a reliable IT information (AG10). The mean is the delivery of programs on time and on budget (AG09). This is in concordance with the target improvements for the MMoH.

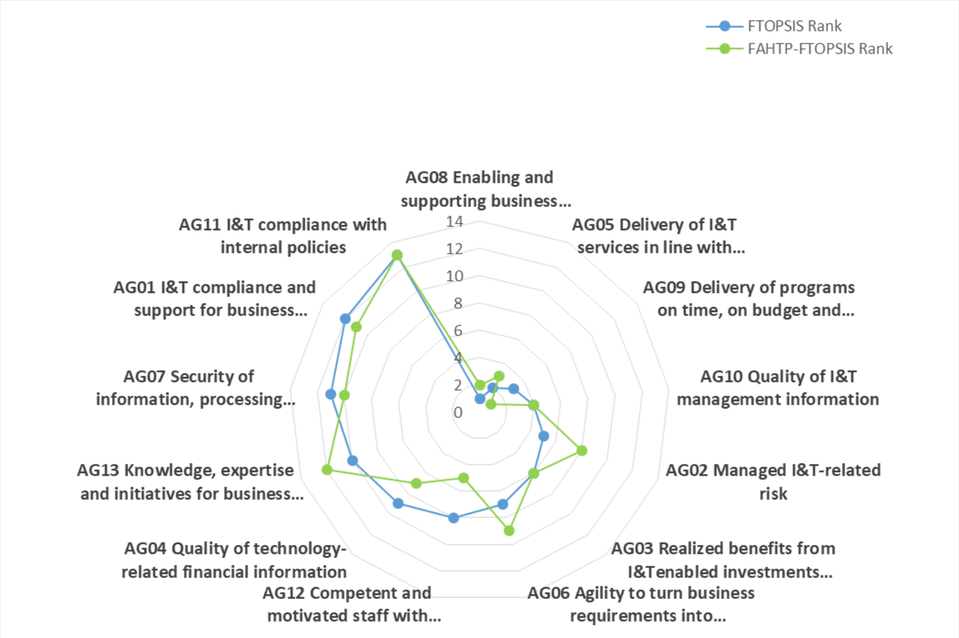


**Figure 9.** Comparison of FTOPSIS ranking and FAHP-FTOPSIS ranking

The other differences and similarities between the two methods are as follows:

- Both methods use the fuzzy theory and linguistic variables which make them suitable to grasp the incompleteness of information at the strategic level.
- The fact that the weights are calculated with a pairwise comparison in FAHP, it gives the DM the opportunity and information about the priority among criteria than Fuzzy TOPSIS.
- The criteria weight computation with the geometric mean used in FAHP make it resilient to the rank reversal problems like For FTOPSIS. The Extended Analysis Method is very used in FAHP in the literature but is not as resilient as the geometric mean (Liu et al., 2020).
- For the alternatives, both methods use FTOPSIS, there is no issue with the rank reversal problem.
- The comparison of both methods allows to form groups of similitudes and even manage risks in case of an alternative increases or decreases its ranks sharply. Having a homogeneous group gives more confidence in the decision.
- Considering the number of criteria (n), FAHP is limited to a maximum of 9 as preconized by Saaty, given the pairwise comparison of $n(n-1)/2$ , the computation increases rapidly and the evaluation by DMs becomes more complex. On the other hand, FTOPSIS has the ability to scale without complexity of computation or difficulty of evaluation for DMs.

## 5. Conclusion

This paper introduced a MCDM based approach to align IT strategy with SC strategy. It compared the FTOPSIS with a hybrid Fuzzy AHP-TOPSIS approach. The performance attributes from the SC SCOR framework give the SC vision and strategy. They represent decision making criteria which include 'Responsiveness, 'Reliability', 'Agility', 'Cost' and 'Asset Management'. Whereas the 13 IT alignment goals of COBIT constitute the alternatives to select from and they translate the IT strategy. The evaluation are made with linguistic variables and the fuzzy set theory allows to deal with incomplete information at a strategic level. An application of both methods was presented for the public pharmaceuticals SC of the Moroccan ministry of Health. The results show that the two MSDM methods have some differences but in general, they tend to be coherent with each other. With FTOPSIS, the criteria are evaluated along with the alternatives with linguistic variables. After the computation of the positive and negative ideals, the distances of IT goals to theses ideals show that the importance is given to the integration of applications, the Delivery of IT and the quality of the information, with the support of delivering programs on time and on budget.

In the hybrid Fuzzy AHP-TOPSIS, the weight of criteria were computed with FAHP. After checking that the CR is below 0.1, theses weights values were used as an input to FTOPSIS to prioritize the IT goals. It gives quite similar results to FTOPSIS. There are 3 groups that appear, the first 4 IT goals are the same than the ones with FTOPSIS. At a strategic level for a mid-term or long term planning, they can be considered as equivalent.

FTOPSIS has some advantages, it can compute a greater number of criteria and alternatives without exponential computational complexity nor the issue of reverse ranking problem. The hybrid FAHP-FTOPSIS with the geometric mean is also resilient to the reverse ranking problem unlike the Extended Analysis Method. In addition, the pairwise comparison between criteria allows to convey more insights about the priority for their ranking. It invites the DMs to be more conscious about the criteria and the vision. However, the pairwise comparison can be a drawback when there is a large number of criteria which make the computation exponential and the evaluation by DMs challenging.

Finally, the study contributes to the IT alignment literature, especially in a SC context. It allows to integrate the IT and SC objectives. The paper enforces the role of Fuzzy MCDM methods in order to make IT complex decisions at a strategic level in a SC context and in a situation where not all the information is available. Having a method that uses computation, standard criteria and objectives gives some neutrality for the process. It also enforces the maturity level of the decision making process: it is formalized and can be measured and facilitate the consensus. The decision process is more controlled which reduces improvisation that can affect the output of the decision.

As perspectives, research can go further with analysing the strategic IT alignment for different type of SC or sectors. Future work will look at the integration of IT and SC with different type of decision like IT architecture, IT processes, IT applications and IT portfolio.

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