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Analytic Hierarchy Process to Choose the Best Sector in the Software Industry for a New Software Engineer

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Abstract

Objectives: To determine the best area in the software industry for a fresh engineering graduate in India. **Methods:** Examined the current situation of the software industry today and the datasets that were gathered and included in accordance with that. Here, five alternatives (Research and Development, Mobile solutions, Cloud computing, Big data analytics, and Government and Defence) and seven parameters (Communication, Teamwork, Coding and technical literacy, Programming languages, Problem-solving skills, Research skills, and Multitasking skills) are taken into consideration. Fuzzy AHP and fuzzy TOPSIS methods were used, and the outcomes were compared to the AHP method. **Findings:** Fuzzy AHP and fuzzy TOPSIS methods have been used to produce the normalized weight vector for each alternative relative to the criterion. Additionally, a normalized weight vector has been calculated and compared to every criterion and criteria alternative. Final rankings for each alternative have been determined in relation to all of these. **Novelty:** The novelty of the present study is to identify the best sector of the software industry in India for a recent engineering graduate based on providing a ranking of alternatives using fuzzy TOPSIS and fuzzy AHP methodologies. While other strategies may be used to do similar works, the techniques listed above may not be used. Fuzzy AHP and fuzzy TOPSIS approaches can provide more optimal solutions, which is an innovative aspect of this study.

Keywords: Analytical Hierarchy Process (AHP); Comparative analysis; Fuzzy AHP method; Fuzzy TOPSIS method; Software industry

1 Introduction

The software industry's revenue has increased significantly over the past ten years, and in the financial year 2021-2022, its proportion to India's GDP is estimated to be between 7% and 8%. India is the most popular offshore location for IT companies worldwide. Seven parameters and five alternatives have been narrowed down after extensive research to determine which area of the software industry is ideal for a new software engineer in India. Rankings for these alternatives have been determined by applying fuzzy AHP and fuzzy TOPSIS methods. These outcomes were compared with those obtained using AHP techniques. A recent graduate in software engineering can select the best sector based on this ranking. Such recent graduates in Engineering will benefit from this study.

The demand for software developers is enormous, and software developers are very unlikely to change anytime soon. Hence, there are valid reasons for anyone to become interested in a career in software engineering. With a basic salary of $96,392 and an amazing 99,055 position, "software engineer" was the most lucrative job title, as indicated by the employment portal Glass Door. This is more than nine times greater than the second highest-paying, in-demand occupation. Between 2012 and 2022, job growth for software developers is predicted to reach 22.8%, which is significantly greater than the national average for all the other occupations.

Software engineers are in high demand due to increased business demands for cloud computing, big data analytics, and mobile solutions, said David Foote, CEO of the IT labor research firm Foote Partners LLC. With so many options available, supply-side IT professionals could find it very challenging to choose where to place their next career wager. It would also be quite difficult, particularly for those who are beginning their journey or are attempting to market themselves in new ways. It always boils down to the person and what they are passionate about. Some are passionate about inventions, while others are about financing. Some people desire a high quality of life, according to Marc Cervoni, managing partner of the employment agency Park Hudson International.

As mentioned below, there are five booming sectors where software experts should anticipate a bright future. These sectors were used as alternatives in the current study.

- Research & Development (A_1)
- Mobile solutions (A_2)
- Cloud computing (A_3)
- Big data analytics (A_4)
- Government & Defense (A_5)

1.1 Research & Development (A_1)

Although there is no separate R&D sector, thousands of traditional businesses have such operations. In game-changing product laboratories, research and development teams, and emerging business divisions, specific types of software engineers are needed. The Western Union, once associated with the telegraph, runs Western Union Digital Ventures, a high-tech innovation lab in San Francisco's SOMA neighborhood. The 170-year-old business has experienced multiple technological revolutions and is now searching for great thinkers in the mobility space to help it ride the wave of digital currency and payments.

Thompson Reuters is another option. A much smaller company, Reuters TV, is part of the $12.6 billion media company and hopes to reimagine video journalism for the next generation. The company, which has reporters working for it all around the world, aims to provide customized, on-demand TV news that is provided by way of mobile devices. For it to work, developers are needed.

1.2 Mobile solutions (A_2)

As more people shift to hybrid working, mobile solutions become the standard technology in all settings, including at home, remote locations, commuting, and on-site workspaces. Regardless of the location of their employees, organizations must integrate and link their devices and apps securely and seamlessly to accommodate this new style of working. Mobile solutions are essential for attracting, empowering, and keeping talent in today's highly competitive and frequently unpredictable workplace. They also help to provide a uniform and predictable experience for employees.

In today's digital environment, flawless predictability, renowned security, and a unified employee experience are essential, whether at private production facilities or remote home offices. The need for even greater capacity and stability across wireless networks is being driven by the shift to the "digital industry" and the development of the volume of data and devices. Businesses may now take advantage of the next generation of network security, speed, capacity, and dependability thanks to the introduction of 5G technology.

Mobile solutions offer appropriate flexibility in terms of device selection, administration tools, data plans, and private wireless access to guarantee that each person is prepared to function well in every setting. Currently, security is a primary responsibility of companies. Employees may have the same degree of security architecture on their mobile devices as they do on their desktop PCs by using the appropriate security solutions.

1.3 Cloud computing (A_3)

The utilization of hosted services, including servers, databases, networks, software, and data storage via the Internet, is referred to as cloud computing. A cloud service provider manages the physical servers where the data are kept. In cloud computing, computer system resources—particularly data storage and processing power—are made available on-demand and are not directly managed by the user.

A user can save files in the cloud, which allows them to be accessible from any location as long as they have internet access, rather than on a hard drive or storage device. Infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS) are the three main categories into which cloud services can be separated. Public, private, and hybrid clouds can also be categorized according to the deployment model. Moreover, cloud computing can be separated into front-end and back-end levels. The front-end layer is the layer with which users interact. Through cloud computing software, a user can access the data stored in the cloud through this layer.

1.4 Big data analytics (A_4)

Finding trends, patterns, and correlations in vast amounts of unprocessed data to support data-driven decision-making is known as big data analytics. With the aid of more recent technologies, these procedures apply well-known statistical analytic techniques—such as regression and clustering—to larger data sets. Early in the new millennium, when advancements in technology and software-enabled enterprises to manage massive volumes of unstructured data, big data became a catchphrase. Since then, many new technologies have added to the significant volumes of data that organizations have access to, from smartphones to Amazon. Early innovation projects, such as the Hadoop, Spark, and NoSQL databases were developed for the processing and storing of large amounts of data in response to the explosion of data.

As data engineers search for methods to combine the enormous amounts of complicated information produced by sensors, networks, transactions, smart devices, and web usage, this field is still developing. To find and scale more sophisticated insights, big data analytics techniques are still being employed with developing technologies such as machine learning.

1.5 Government & Defense (A_5)

Anyone can take the government-industrial complex into account if they have chosen to concentrate on security software development. From municipal and state governments to federal organizations and government contractors, there is a strong demand for safe software programmers with relevant skills and certifications.

This is a truly high-demand sector. These individuals are in high demand and will obtain further certification and federal clearance in these positions as well, paving the door for a lengthy career in employment with the government. Furthermore, industries that are currently insufficient investment in secure coding will soon search for professionals with a background working with governmental organizations.

Criteria: The following is a list of abilities needed by software engineers. These competencies were utilized as criteria in the present study.

- Communication (C_1)
- Teamwork (C_2)
- Coding and technical literacy (C_3)
- Programming languages (C_4)
- Problem-solving skills (C_5)
- Research skills (C_6)
- Multitasking skills (C_7)

1.6 Communication

Teamwork not only improves efficiency but also boosts productivity in many software development projects. Software engineers must be effective communicators since they often have to collaborate with other engineers or explain complex software ideas to accomplish a task. For instance, a software engineer might work with artists to create web apps.

1.7 Teamwork

Many software developers who supply services and manage systems prefer teamwork. Being able to convey project requirements, listening to feedback and taking it in stride, and showing respect for their teammates are all aspects of teamwork. It may be necessary to work together with others to develop new ideas during brainstorming sessions; therefore, teamwork is crucial. Although working in software engineering is typically solitary, there may be occasions when you need to work closely with other team members.

1.8 Coding and technical literacy

The process of developing a collection of computer-executable instructions is known as coding. A company always puts this as a technical necessity on a job ad because it is the foundation of software programming. Therefore, to become a software engineer, mastering one or more coding languages is essential.

1.9 Programming languages

An employer may highlight one of the programming languages on the following list in a job offering for a software engineer:
C#, C++, HTML, Java, JavaScript, Perl, PHP, and Python.

1.10 Problem-solving skills

Problem-solving abilities are required in the workplace. This approach entails determining the cause of an issue and devising a suitable remedy. Software testing and debugging are two tasks that require this knowledge. Patience, inventiveness, ingenuity, and critical thinking are also required for determining the root cause of an issue and devising realistic solutions.

1.11 Research skills

Research abilities are the capacity to compile, arrange, evaluate, and interpret data on a specific subject. Critical analysis, search, and inquiry abilities are all part of research capabilities. For professions in software development, conducting research is a crucial ability that workers require to address issues and provide answers.

1.12 Multitasking skills

Multitasking is the practice of managing several tasks at once. Being organized and setting priorities while managing multiple projects with tight deadlines may be required for a software developer. Utilizing time management strategies will help individuals to stay efficient and productive.

The AHP technique was used in the research article “An AHP-based Approach to Selecting a Priority Public Transportation Mode for Investment” which was published by Mohamed Akhrouf et al.[(1)]. Another article by Nima Moradi[(2)] that employed the AHP technique is “Performance Evaluation of University Faculty by Combining BSC, AHP, and TOPSIS: From the Student’s Perspective”.

The AHP is chosen as an MCDM technique to find the optimal software area for a new software engineer due to its popularity and widespread use in business. Because AHP is well-liked and frequently used in the industry, we decided to use it as our MCDM technique to handle the software field selection dilemma. To organize and analyze complicated circumstances, the AHP is frequently employed. Instead of prescribing the optimum course of action, the AHP assists in identifying the option that best serves the objective and comprehension of the situation of the decision maker. It is an organized process that uses a methodical approach. It offers a thorough and logical structure for resolving a decision-making issue.

The AHP is frequently employed in a variety of decision-making circumstances. It has been used in many different fields, including administration, business, manufacturing, healthcare, and education. AHP is not a particularly new technique, but it has recently gained much popularity. Many scientists are combining the strength of AHP with other approaches. AHP approach such as “State-of-the-Art Review on the Analytic Hierarchy Process with Benefits, Opportunities, Costs, and Risks” was explained by Antonella Petrillo et al.[(3)]. The AHP techniques were used by Jana Stofkova et al.[(4)] in “Use of the Analytic Hierarchy Process and Selected Methods in the Managerial Decision-Making Process in the Context of Sustainable Development”.

The AHP was utilized by Sarbast Moslem et al.[(5)] in “A Systematic Review of Analytic Hierarchy Process Applications to Solve Transportation Problems: From 2003 to 2022”. The AHP was used by Madzı´k P and Fala´t L[(6)] in their article “State-of-the-art on analytic hierarchy process in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modeling”.

Alessio Ishizaka, and Enrique Mu[7] employed the AHP approach for the evaluation and selection of projects in "What is so special about the analytic hierarchy and network process?". Additionally, authors cited publications Yan Liu et al.[8] for "A review of fuzzy AHP methods for decision-making with subjective judgements" and Mohd Nazim et al.[9] for "A comparison between fuzzy AHP and fuzzy TOPSIS methods to software requirements selection".

Several academics in a number of disciplines have widely used multicriteria decision-analysis (MCDA) methodologies. The technique for order preference by similarity to ideal solution (TOPSIS) under a fuzzy environment, also known as fuzzy TOPSIS, is one of the numerous MCDA methods that has been successfully applied to a variety of practical, real-world issues.

2 Case study

India is experiencing rapid growth in the software sector and has a thriving worldwide software development business. To remain successful in the market in today's cutthroat environment, software companies must optimize the value created by their products. The completion of requirements is a key factor in how valuable a software solution is. As a result, it is crucial to choose the criteria for a given software release carefully. The importance of various decision-making criteria and the perspectives that drive them are examined empirically in this work to better understand how value is created. The research is conducted among international software firms operating in India. The relative relevance of the variables is determined using the analytical hierarchy technique. In the majority of nations, including the U.S., software engineers are among the highest-paid professionals. A software professional in the U.S. makes, on average, 139,470 dollars per year, with an extra 15,243 dollars in cash benefits. A lucrative professional path with many opportunities for financial security is software engineering. Software engineers earn high salaries because their knowledge is essential to many businesses and organizations. This is especially true in the digital era, where software and systems are essential for daily operations. Additionally, they must receive adequate compensation for their demanding and arduous work. The demand for software engineers increased along with the demand for software engineering across all the IT sectors. This demand suggests that software engineering will be a viable career choice in the years to come and that software engineers will unquestionably dominate the IT sector.

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3 Methodology

The triangular fuzzy scale, used in this investigation, is listed in Table 1.

Table 1. Triangular Fuzzy Scale

Crisp No	Triangular Fuzzy Number	Definition
1	(1,1,1)	Equal importance
3	(1,3,5)	Little more significant than the other
5	(3,5,7)	Important or very important
7	(5,7,9)	Very strong importance
9	(7,9,11)	Extremely important
2,4,6,8	(1,2,4),(2,4,6),(4,6,8), (6,8,10)	Intermediate values

3.1 Fuzzy AHP Method

Step- 1: For pairwise comparisons of all criteria, each decision maker assigns a linguistic phrase, represented by a triangular FN. Let $\widetilde{P}$= $[\widetilde{a_{ij}}]$ be an n × n matrix, where $\widetilde{a_{ij}}$is the importance of criterion C $_i$ with respect to criterion C $_j$,

$$\widetilde{P}=\begin{bmatrix}(1,1,1) & \widetilde{a}_{12} & \dots & \widetilde{a}_{1n}\\ \widetilde{a}_{21} & (1,1,1) & \dots & \widetilde{a}_{2n}\\ \dots & \dots & \dots & \dots\\ \widetilde{a}_{n1} & \widetilde{a}_{n2} & .. & (1,1,1)\end{bmatrix}$$

Step- 2: Calculate the normalized fuzzy weights. To determine the fuzzy weight of criterion C$_i$, the indicated formula is used.

$\widetilde{w}_i$= $\widetilde{r}_i \times (\widetilde{r}_1+\widetilde{r}_2+\cdots+\widetilde{r}_n)^{-1}$, where $\widetilde{r}_i=[\widetilde{a}_{i1}\times\widetilde{a}_{i2}\times\dots\times\widetilde{a}_{in}]^{\frac{1}{n}}$

3.2 Fuzzy TOPSIS Method

The most well-known methods for overcoming MCDM difficulties are Hwang and Yoon's Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) Method. This method is based on the premise that the final option should be the option that is closest to the positive ideal solution (PIS), which maximizes benefits while minimizing expenses, and the option that is farthest away from the negative ideal solution (NIS). Chen added triangular FNs to TOPSIS. The vertex method was developed by Chen to determine the separation between two triangular FNs.

If $\widetilde{x} = (a_1,\ b_1,\ c_1)$, and $\widetilde{y} = (a_2,\ b_2,\ c_2)$are two triangular FNs then

$$d\left(\widetilde{x},\ \widetilde{y}\right) = \sqrt{\frac{1}{3}\left[(a_1-a_2)^2+(b_1-b_2)^2+(c_1-c_2)^2\right]}$$

Procedure:

Step- 1: Give the alternatives and the criteria ratings. Consider a decision-making group with K members. With regard to criterion C_j, the kth decision maker's fuzzy rating for alternative A_i is shown by- $\widetilde{x}_{ij}^k = \left(\widetilde{a}_{ij}^k, \widetilde{b}_{ij}^k, \widetilde{c}_{ij}^k\right)$ and the weight of criterion C_j is indicated by- $\widetilde{w}_j^k = (\widetilde{w}_{j1}^k, \widetilde{w}_{j2}^k, \widetilde{w}_{j3}^k)$.

Step- 2: Calculate the aggregated fuzzy weights and aggregated fuzzy ratings for the criteria and alternatives. The aggregated fuzzy rating $\widetilde{x}_{ij} = (\widetilde{a}_{ij}, \widetilde{b}_{ij}, \widetilde{c}_{ij})$ of the ith alternative with respect to the jth criterion is calculated as given below.

$$a_{ij} = \underset{k}{min}\ \{\widetilde{a}_{ij}^k\},\ b_{ij} = \frac{1}{K}\sum_{k=1}^{k}\widetilde{b}_{ij}^k,\ c_{ij} = \underset{k}{max}\ \{\widetilde{c}_{ij}^k\}.$$

The aggregated fuzzy weight $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ for C_j can be obtained as follows:

$$w_{j1} = \underset{k}{min}\ \{w_{j1}^k\}, w_{j2} = \frac{1}{K}\sum_{k=1}^{k} w_{j2}^k,\ w_{j3} = \underset{k}{max}\ \{w_{j3}^k\}.$$

Step- 3: The normalized fuzzy decision matrix should be computed. The normalized fuzzy decision matrix is- $\widetilde{R} = [\widetilde{r}_{ij}]$, where

$\widetilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right)$ and $c_j^* = \underset{i}{max}\ \{c_{ij}\}$ (Benefit criteria)

$\widetilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right)$ and $c_j^- = \underset{i}{min}\ \{a_{ij}\}$ (Cost criteria)

Step- 4: Create a weighted normalized fuzzy decision matrix. The weighted normalized fuzzy decision matrix is- $\widetilde{V} = (\widetilde{v}_{ij})$, where $\widetilde{v}_{ij} = \widetilde{r}_{ij} \times w_j$.

Step- 5: Calculate the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) as follows:

$A^* = \left(\widetilde{v}_1^*, \widetilde{v}_2^*, \ldots, \widetilde{v}_n^*\right)$ where $\widetilde{v}_j^* = \underset{i}{max}\ \{v_{ij3}\}$; $A^- = \left(\widetilde{v}_1^-, \widetilde{v}_2^-, \ldots, \widetilde{v}_n^-\right)$ where $\widetilde{v}_j^- = \underset{i}{min}\ \{v_{ij1}\}$

Step- 6: Calculate the distance from each alternative to the FPIS and to the FNIS. Let $d_i^* = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^*)$, and $d_i^- = \sum_{j=1}^n d(\widetilde{v}_{ij}, \widetilde{v}_j^-)$be the distances from each alternative to the FPIS and to the FNIS, respectively. Compute the closeness coefficient CC_i for each alternative. For each alternative Ai we calculate the closeness coefficient CC_ias follows:

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

Step- 7: Sort the options in order. The best alternative is the one with the highest proximity coefficient.

4 Results and Discussion

Comparative discussion: In order to determine which sector of the software industry is best for a new software engineer, a comparative analysis using the AHP, fuzzy AHP TOPSIS methods has been conducted. Seven criteria and five sectors were taken into account. With a final weight of 0.858 by the fuzzy AHP TOPSIS method and 0.34 by the AHP method, Big data analytics is the best sector in the software industry, according to the weighting results of both methodologies. Cloud computing is next, followed by Mobile solution, Government & Defense and Research & development.

Table 2 presents fuzzy alternatives along with their relative importance to each of the criteria. The normalized weight vector and consistency ratio are also included in this table.

Table 2. Normalized weight vectors of fuzzy alternatives with respect to the criteria

Criteria(↓)	Alternatives	A_1	A_2	A_3	A_4	A_5	C.R	Normalized weight vector
Communication(C_1)	A_1	1	1/3	3	1/5	1	0.09	(0.05,0.11,0.26)
	A_2	3	1	4	1/2	5		(0.11,0.3,0.7)
	A_3	1/3	1/4	1	1/5	3		(0.03,0.08,0.23)
	A_4	5	2	5	1	5		(0.2,0.45,1.01)
	A_5	1	1/5	1/3	1/5	1		(0.03,0.06,0.15)
Teamwork(C_2)	A_1	1	1/3	3	1/5	5	0.08	(0.06,0.15,0.39)
	A_2	3	1	4	1/2	5		(0.11,0.29,0.69)
	A_3	1/3	1/4	1	1/5	3		(0.03,0.08,0.23)
	A_4	5	2	5	1	5		(0.19,0.44,1.01)
	A_5	1/5	1/5	1/3	1/5	1		(0.02,0.04,0.12)
Coding and technical literacy(C_3)	A_1	1	1	1/5	1/3	1/2	0.05	(0.04,0.08,0.21)
	A_2	1	1	1/5	1/6	1/3		(0.03,0.06,0.16)
	A_3	5	5	1	3	2		(0.15,0.42,1.06)
	A_4	3	6	1/3	1	3		(0.09,0.28,0.77)
	A_5	2	3	1/2	1/3	1		(0.05,0.16,0.49)
Programming languages(C_4)	A_1	1	1	1/3	1/5	1/2	0.03	(0.04,0.07,0.20)
	A_2	1	1	1/4	1/6	1/3		(0.03,0.06,0.16)
	A_3	3	4	1	1/3	3		(0.08,0.24,0.67)
	A_4	5	6	3	1	5		(0.2,0.5,1.12)
	A_5	2	3	1/3	1/5	1		(0.05,0.12,0.36)
Problem-solving skills(C_5)	A_1	1	2	1/5	1/3	1/2	0.04	(0.04,0.09,0.3)
	A_2	1/2	1	1/5	1/4	1/3		(0.03,0.06,0.2)
	A_3	5	5	1	3	2		(0.15,0.43,1.11)
	A_4	3	4	1/3	1	3		(0.08,0.26,0.76)
	A_5	2	3	1/2	1/3	1		(0.05,0.16,0.51)
Research skills(C_6)	A_1	1	3	1/4	1/2	1/3	0.08	(0.04,0.11,0.39)
	A_2	1/3	1	1/5	1/3	1/2		(0.03,0.07,0.26)
	A_3	4	5	1	3	2		(0.12,0.4,1.17)
	A_4	2	3	1/3	1	3		(0.07,0.24,0.82)
	A_5	3	2	1/2	1/3	1		(0.06,0.17,0.07)
Multitasking skills(C_7)	A_1	1	1/3	1/2	1/5	1/4	0.08	(0.03,0.06,0.2)
	A_2	3	1	5	3	2		(0.12,0.4,1.09)
	A_3	2	1/5	1	1/3	1/2		(0.04,0.09,0.31)
	A_4	5	1/3	3	1	3		(0.09,0.28,0.82)
	A_5	4	1/2	2	1/3	1		(0.06,0.17,0.05)

Fuzzy choices with the weights of each criterion are explained in Table 3. The normalized weight vector is also included in this table.

Table 3. Fuzzy options showing the weights of all criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	Normalized weight vector
C_1	1	1/3	1/5	1/5	1/3	5	3	(0.03,0.09,0.29)
C_2	3	1	3	5	1/3	3	1/5	(0.05,0.18,0.53)
C_3	5	1/3	1	3	1/3	3	5	(0.07,0.21,0.65)
C_4	5	1/5	1/3	1	5	5	1/3	(0.06,0.15,0.46)
C_5	3	3	3	1/5	1	1/3	5	(0.05,0.18,0.53)
C_6	1/5	1/3	1/3	1/5	3	1	3	(0.03,0.08,0.27)
C_7	1/3	5	1/5	3	1/5	1/3	1	(0.03,0.09,0.29)

The weighted normalized fuzzy decision matrix values of each alternative are displayed in Table 4 below.
The distance from the Fuzzy Positive Ideal Solution is explained in Table 5.

Table 4. Weighted normalized fuzzy decision matrix

	C 1	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**
A 1	(0.002, 0.010, 0.075)	(0.003, 0.026, 0.204)	(0.002, 0.016, 0.132)	(0.002, 0.010, 0.082)	(0.002, 0.015, 0.142)	(0.001, 0.008, 0.091)	(0.001, 0.005, 0.05)
A 2	(0.004, 0.026, 0.196)	(0.006, 0.052, 0.364)	(0.002, 0.013, 0.1)	(0.002, 0.009, 0.067)	(0.001, 0.010, 0.093)	(0.001, 0.005, 0.061)	(0.004, 0.033, 0.29)
A 3	(0.001, 0.007, 0.065)	(0.002, 0.015, 0.120)	(0.010, 0.085, 0.650)	(0.004, 0.034, 0.277)	(0.007, 0.071, 0.53)	(0.003, 0.029, 0.272)	(0.001, 0.008, 0.08)
A 4	(0.006, 0.04, 0.29)	(0.010, 0.080, 0.535)	(0.006, 0.056, 0.5)	(0.011, 0.069, 0.518)	(0.004, 0.043, 0.405)	(0.002, 0.018, 0.222)	(0.003, 0.023, 0.24)
A 5	(0.001, 0.006, 0.043)	(0.001, 0.008, 0.065)	(0.003, 0.031, 0.299)	(0.003, 0.017, 0.149)	(0.003, 0.026, 0.243)	(0.001, 0.012, 0.016)	(0.002, 0.014, 0.01)

Table 5. Distance from the Fuzzy Positive Ideal Solution

	Distance from FPIS							**d***
	C 1	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	
A 1	0.125	0.194	0.302	0.254	0.226	0.105	0.135	1.341
A 2	0.054	0.100	0.321	0.262	0.254	0.123	0.000	1.114
A 3	0.131	0.242	0.000	0.140	0.000	0.000	0.119	0.632
A 4	0.000	0.000	0.089	0.000	0.074	0.030	0.030	0.223
A 5	0.144	0.275	0.205	0.215	0.167	0.148	0.158	1.312

Distance from Fuzzy Negative Ideal Solution is explained in Table 6.

Table 6. The distance from the Fuzzy Negative Ideal Solution

	Distance from FNIS							**d⁻**
	C 1	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	
A 1	0.018	0.081	0.018	0.008	0.028	0.043	0.024	0.220
A 2	0.089	0.175	0.000	0.000	0.000	0.026	0.159	0.449
A 3	0.012	0.032	0.321	0.122	0.254	0.148	0.040	0.929
A 4	0.144	0.275	0.232	0.262	0.181	0.119	0.129	1.342
A 5	0.000	0.000	0.115	0.047	0.087	0.004	0.005	0.258

The weights of each alternative according to the AHP method are shown in Table 7. These weights were computed in order to compare the weights obtained by the fuzzy AHP and fuzzy TOPSIS methods.

Table 7. Weights of each alternative by the AHP method

	0.09	0.17	0.17	0.16	0.17	0.09	0.12	**Weights**
	C 1	**C 2**	**C 3**	**C 4**	**C 5**	**C 6**	**C 7**	
A 1	0.11	0.15	0.07	0.07	0.08	0.10	0.06	0.09
A 2	0.28	0.28	0.06	0.06	0.05	0.65	0.43	0.21
A 3	0.09	0.08	0.43	0.24	0.43	0.41	0.08	0.25
A 4	0.44	0.44	0.28	0.50	0.26	0.24	0.25	0.34
A 5	0.06	0.46	0.15	0.12	0.15	0.17	0.16	0.19

Table 8 presents the ranking of each alternative as determined by the aforementioned methods.

Table 8. Ranking of Alternatives obtained by the AHP and fuzzy AHP TOPSIS methods

Alternatives	Weights by the fuzzy AHP & fuzzy TOPSIS methods	Ranking according to the fuzzy AHP & fuzzy TOPSIS methods	Weights by the AHP method	Ranking according to the AHP method
A_1	0.141	5	0.09	5
A_2	0.287	3	0.21	3
A_3	0.595	2	0.25	2
A_4	0.858	1	0.34	1
A_5	0.164	4	0.19	4

5 Conclusion

Rankings have been determined by comparing the weights obtained by the AHP and fuzzy AHP TOPSIS methods. These results are compared, and it is determined that the rankings were the same. With a final weight of 0.858 by the fuzzy AHP TOPSIS method and 0.34 by the AHP method, Big data analytics is the best sector in the software industry, according to the weighting results of both methodologies. Cloud computing is next, with final weights of 0.595 (fuzzy AHP TOPSIS) and 0.25 (AHP) followed by Mobile solution with 0.287 (fuzzy AHP TOPSIS) and 0.21 (AHP), Government & Defense with 0.164 (0.19) and Research & development with 0.141 (0.09). The methodology used here can be applied in similar decision-making situations where alternatives are ranked according to different criteria.

References

1) Akhrouf M, Medjamia H, Bessou M. An AHP-Based Approach to Selecting a Priority Public Transportation Mode for Investment. *International Journal of the Analytic Hierarchy Process*. 2023;15(3):1–23. Available from: https://dx.doi.org/10.13033/ijahp.v15i3.1150.
2) Moradi N. Performance Evaluation of University Faculty by Combining BSC, AHP and TOPSIS: From the Students' Perspective. *International Journal of the Analytic Hierarchy Process*. 2022;14(2):1–29. Available from: https://dx.doi.org/10.13033/ijahp.v14i2.915.
3) Petrillo A, Salomon VAP, Tramarico CL. State-of-the-Art Review on the Analytic Hierarchy Process with Benefits, Opportunities, Costs, and Risks. *Journal of Risk and Financial Management*. 2023;16(8):1–16. Available from: https://dx.doi.org/10.3390/jrfm16080372.
4) Stofkova J, Krejnus M, Stofkova KR, Malega P, Binasova V. Use of the Analytic Hierarchy Process and Selected Methods in the Managerial Decision-Making Process in the Context of Sustainable Development. *Sustainability*. 2022;14(18):1–20. Available from: https://dx.doi.org/10.3390/su141811546.
5) Moslem S, Saraji MK, Mardani A, Alkharabsheh A, Duleba S, Esztergar-Kiss D. A Systematic Review of Analytic Hierarchy Process Applications to Solve Transportation Problems: From 2003 to 2022. *IEEE Access*. 2023;11:11973–11990. Available from: https://dx.doi.org/10.1109/access.2023.3234298.
6) k PM, t LF. State-of-the-art on analytic hierarchy process in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modelling. *PLoS ONE*. 2022;17(5):1–31. Available from: https://doi.org/10.1371/journal.pone.0268777.
7) Ishizaka A, Mu E. What is so special about the analytic hierarchy and network process? *Annals of Operations Research*. 2023;326(2):625–634. Available from: https://dx.doi.org/10.1007/s10479-023-05412-4.
8) Liu Y, Eckert CM, Earl C. A review of fuzzy AHP methods for decision-making with subjective judgements. *Expert Systems with Applications*. 2020;161. Available from: https://dx.doi.org/10.1016/j.eswa.2020.113738.
9) Nazim M, Mohammad CW, Sadiq M. A comparison between fuzzy AHP and fuzzy TOPSIS methods to software requirements selection. *Alexandria Engineering Journal*. 2022;61(12):10851–10870. Available from: https://dx.doi.org/10.1016/j.aej.2022.04.005.