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Hesitant-Fuzzy Sets-Based Computational Approach for Evaluating the Survivability Impact of Multi-Fiber WDM Networks: Kingdom of Saudi Arabia Perspective

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ABSTRACT Saudi Arabia's Information and Communication Technology (ICT) industry is undergoing different stages of modernization. Over the last few decades, the ICT industry has been experiencing rapid growth. The understanding of disruption as well as fluctuation in channel capacity gives an idea about the optical fiber network. A primary necessity for the optical communication industry is to achieve the desired effect of survival and growth. Scientific researchers are trying to achieve the objective of optimum optical network services survivability. The proposed paper attempts to describe and analyze the effect of multiplexing in multi-fiber wavelength. To analyze and assess the effect in more scientific and systematic manner, the authors have used a multi criteria decision making (MCDM) approach named the hesitant fuzzy analytical hierarchy process as well as TOPSIS methods in this paper. With the help of these adopted MCDM approaches, the authors have assessed the surviving strength and capacity of multiplexing. For this empirical model, five features and two levels of alternatives were chosen. A combination of two principal alternatives was the first level, and the second level had its five based alternatives. For this analysis, the unified symmetrical decision making strategy of Hesitant-Fuzzy AHP with Hesitant-Fuzzy TOPSIS was established. The findings obtained on survivability in this research will be a point of reference for developing the next level wavelength division multiplexing in optical transmission network communication. In the sense of producing gigabits and terabits per second, this inquiry will further reinforce optical fiber connectivity.

INDEX TERMS Survivability of wavelength division multiplexing (WDM), optical network systems, decision making, Hesitant-Fuzzy TOPSIS, Hesitant-Fuzzy AHP.

I. INTRODUCTION

Network survivability in the connectivity of the optical fiber network guarantees the network operator's continuous operations. Natural catastrophes, such as earthquakes, tsunamis, floods, etc., interrupt the communication of the optical fiber. Network failures caused due to interruptions often result in the loss of data loss, creating issues for both the transmitter and the recipient. Therefore, consistent ingenuity of restoration and security approaches has become an inevitable requirement for achieving the goal for smooth and uninterrupted operations. The attribute known as survivability may be preserved by network or information leakage during transmission of data or contact between two or more individuals. The network utilizes the multiplexing network of the carrier wavelength segment identified by the laser light as symmetric multi-signal optical communication systems. To prevent issues that arise due to human error or natural calamities, the authors have provided connectivity in the multiplexing network of wavelength segment by the attribute of survival. Survivability is based on different features. The frequency of degradation of optical networks is important. The intermediate period between failures is approximately 367 years per km [1]. As per NSFNet, in a 26000 km wide optical fiber based network, there is one fiber cut in 5 days [2]. There is an even greater probability of two simultaneous faults in

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the optical network; roughly 0.0027 as opposed to 24 hours a year[3]. The wavelength segment multiplexing network's survival means the network's way to safeguard and protect information with the help of optical fiber data transmission during processing.

There are different types of failures in the optical communication system, such as, the port failure, hardware failures, fiber cutting, duct inability, and channel disruption. The channel is an external pipe between nodes in which optical fibers are stored in cables for optical fiber based network communication. In case of an earthquake or any other such destructive event, the duct failure can occur and the optical network might be displaced. The light path may collapse and the fiber may be interrupted, resulting in the loss of traffic. Node failures are caused by fire or floods. In optical fiber based network communication, the disturbances or failures attributable to hardware failures are equally detrimental. Channel loss in the communication of the optical fiber network is triggered by devices used for channel creation through the receiver and transmitter. Survivability of the network is a significant hurdle for transmission in real time. In the wavelength segment multiplexing network, probable failures are significant. In addition, optimizing the accessibility of links in the Wavelength Division Multiplexing (WDM)system after interruption often causes disruption of the network.

Port errors which appear in the network router are the other faults of optical fiber network communication. These kinds of failures are the foundation of the survivability of optical transmission networks. For the anticipated survey of survival in the wavelength segment multiplexing network, these justifications of failure were taken into account.

In order to assess the longevity and commercial feasibility of the optical fiber network, it is significant to explain the requirements and effect of survivability features. The numerical assessment of surviving factors for multiplexer as suggested in this study will be an effective mechanism for tackling and preventing adverse effects of losses in optical fiber ntworks. There is indeed a compromise between some of the optical network's survival and cost [4], and committed path safety, as propositioned, will achieve 100% survival.The researchers have specifically chosen the security and restoration strategies as the first level of features (T1) and (T2) in the observed statistical analysis. In addition, this analysis involves a combined strcture of methodology that associate hesitant fuzzy based AHP and TOPSIS approachesto assess the effect of survivability on different features and alternatives. The key goals of this research are:

1) To evaluate the effect of functionality.
2) Security numerical study of multiplexing network wavelength division in contact with optical fiber networks.
3) Numerical review of the security and recovery strategy.

Such assumptions would allow the experts to render the multiplexing network for wavelength division quite survivable. Survivability allows the protection of data through the transmission system. In this research, the unified symmetrical method of Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS has been used to determine the weight and ranking of the features, accordingly. In the wavelength segment multiplexing network, Hesitant-Fuzzy AHP prioritises the survival features and alternatives. The features and respective alternatives are rated by Hesitant-Fuzzy TOPSIS. The specialists have a set of features from which the unique characteristics that decide survivability in the multiplexing network wavelength segment have to be chosen. As specialists have to choose the features of the highest choice for different requirements, this method calls for selective decision making. In the present study, the researchers opted for the unified symmetrical system of Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS to perform survivability numerical study in the multiplexing wavelength segment network to resolve this problem.

Rest of the article is organized as: The research searched for documenting this study has been enunciated in section 2. In the wavelength segment multiplexing network, section 3 explains different features, alternatives as well as survivability. Adopted methodology is breifly described in section 4. Section 5 describes the statistical evaluation and its validation, while section 6 discusses the assumptions and examines the findings. Section 7 concludes the research underlining the importance of the survival feature in the multiplexing network of wavelength segment.

II. PREVIOUS WORK

Numerous studies have been carried out on wavelength segment multiplexing networks that discuss survivability recovery and security schemes in the context of optical fiber network communication. These studies have incorporated various methods that focus on different features that influence the transmission of the optical fiber network. In the background of several network deployment methods, survivability has always been the elemental interest of the researchers. More critical is the protection of the data transmitted via the network infrastructure. Effective and stable optical communication must therefore ensure efficient and comprehensive data transfer over the connectivity of the optical fiber network. Primarily, this study is aimed at highlighting the essentialness of the factors that influence the survival of optical fiber communication. Thereafter, the authors have analyzed the properties and their corresponding weights leveraging Hesitant-Fuzzy AHP. In the ensuing steps, the corresponding properties have been reevaluated for the rating through Hesitant-Fuzzy TOPSIS on the basis of the weights received. The related literature references that guided the present research premise on the survival of the optical fiber network are listed below during the characterization of this research:

Zhu *et al.* [5] presented a model test in which they assesed the litreature about distributing fiber optical network associated with fiber bragg grating approach for resolving issues like the soil nail observation, and many other similar contexts.

Wang *et al.* [6] outlined the loss and delay in the life cycle of sensors, and also recognized the three layer transfer method for strains that assess errors. Role of sensor on its host network is also analyzed and described in the paper. After a successful analysis, the paper classifies the sensing length for debounding, senstivity of results and adopted attributes also gets evaluated in this paper. Wang *et al.* [7] presented categorized sensors, for example, a point to point based design methodology and its analysis. The results established that the strain transfer approaches and techniques were more benificial and effective.

Wu *et al.* [8] presented an indication of the state-of-the-art progress and submission of optical fiber associated network design from following two perspectives: 1) Fiber Bragg grating (FBG) based sensing and monitoring technology; 2) Distributed optical fiber sensors (DOFS) including Brillouin Optical Time Domain Reflectometry (BOTDR) and Brillouin Optical Time Domain Analysis (BOTDA). Further, it also tells about the issues and relevant obstacles of field breifly.

Alenezi *et al.* [9] examined the software security attributes from adopting a MCDM methodology, similar to the proposed article to determine the weights of the software security features [9].The study discussed about various factors of software security and numerically ases them by Hesitant-Fuzzy AHP approach. This research has also implemented Hesitant-Fuzzy AHP model for measuring and studying the impact of survivability in wavelength division multiplexing network.

Kumar *et al.* [10] proposed a study that bridged the gap of usability in software. The study stated that usability as well as security in software are relatable. In order to assess this statement, the authors selected various factors of security and usability. The study adopted Hesitant-Fuzzy TOPSIS approach to evaluate these selected factors.The investigation dedicated on analysing the threat of the software and usability, and the numerical analyses completed in the investigation sought to improve the quality as well as security of web application.

Similarly, in the present context also, the authors have adopted the hesitant fuzzy sets based approach to measure the survivability of wavelength division multiplexing network. Moreover, the aforementioned studies also corroborate the importance of the investigations based on the unified symmetrical hybrid approach.

III. WAVELENGTH DIVISION MULTIPLEXING SURVIVABILITY IN OPTICAL FIBER NETWORK COMMUNICATION

It is often seen that the data loss is also the cause of money related loss in optical fiber networks. Authors found that survivability is also one of the most significant factors that can lead to data loss. The proposed article aims to evaluate survival of multiplexing network wavelength segment as well as its alternatives. More specifically, the proposed investigation intends to assess the quantitative evaluation of the survival of relevant preservation and recovery features on their contingent attributes. In this background, the features and their dependent alternatives are discussed in the current section. Availability [S1], Service Reliability [S2], Restoration Time [S3], Service Restorability [S4], and Dynamic Restoration [S5] are alternatives which significantly impact survivability. The alternatives are the individuals on which the survivability trait relies. According to the need and significance of dependent features used in optical fiber network communication, the researchers have chosen features through the decision-making method. These features are divided into two key components: Protection [T1] and Restoration [T2]. Each key factor is further categorized into five dependent features.

Survivability Features in Wavelength Division Multiplexing-Survivability comprises two levels of features known as primary level protection and recovery. In addition, in each level, protection and restoration include five components:

A. PROTECTION (T1)

For the survival of the wavelength division multiplexing system, protection is an essential activity. Interaction between the entities tends to occur over the optical fiber in the usual operating state of the communications fiber. When a malfunction occurs, the network connectivity for which a recovery route is chosen is disrupted [12]. The circumstances under which communication works without interruption between the entities are called protection. The protection in this research is the first level of features. Protection in the wavelength division multiplexing channel has five separate dependent features in the sub-category of survivability features.

1) FAILURE FREQUENCY (T11)

The optical network problem that is caused for a certain time period is considered under this frequency [13]. Both physical contacts in the wavelength division multiplexing system are two unidirectional fibers in the reverse way. There are a certain number of wavelengths defined as the wavelength channel for each fiber. Connection failures as well as node failures are the problems. The survival of the optical fiber has been discussed by using a single connection failure. It was seen by the researchers as a function of this evaluation.

2) FAILURE REPAIR RATE (T12)

Various error related situations are frequently penetrating alternatives from 1 to 5 [14]. Unsuccessful numerical solution is the failure repair rate if the route is multi fibers. The failure repair rate is increasing in first alternative. More significant than the F5 is the alternative A1. Each path's failure rate is distributed progressively with a significant value.

3) DEDICATED PATH PROTECTION (T13)

For securing every path there is backup way for specialized path protection that is designated for optical fibers. For data transfer, link mutual path and wavelength are allocated. The communication channel is used for data transfer when an error occurs. It increases the survival of the multiplexing network for wavelength segment. Here, the (T13) was considered by the researchers to be the second layer function of wavelength division multiplexing network survival.

4) SHARED PATH PROTECTION (T14)

A communication, disjoint backups route and wavelength are allocated for optical data transfer at the time of transfer on a route. For the duration of error, the allocated path may be decided to share with some other path of communication. Compared to (T13), this security technique enables the network cost-effective.

5) PATH PROTECTION (T15)

The communication section of the transmitter and receiver are linked to the terminal. Modules need a backup in error situation in each link; the link finds the backups and recovery in various channels [15].

B. RESTORATION (T2)

Securing and backup paths are crucial entities in the wavelength division multiplexing system. Securing approaches are associated with security, performance and maintainability related attributes like performance capacity of spare. In contrast to reconstruction, characteristics associated with safety take less time. Restoration makes better use of resources than a method of protection. In case of error, optical network restore results into an adaptive search to recover the route. The restoration method restores the impacted network traffic during the network failure status [12]. Survivability factors also get affected by multiplexing network in wavelength segment. If the protection intensity increases, different wavelength division multiplexing network alternatives can be reduced.

1) DISRUPTION HOLDING TIME (T21)

The multiplexing wavelength division network has enormous capabilities and a complex circuit that offers excellent frequency keeping time [13]. The potential to rebound from loss means survivability. The hold time is taken advantage of and renders the communication unsafe without taking into account the availability of the shared route. Availability is ensured by collective and optimistic route protection. Through holding time, the researchers lowered the auxiliary potential.

2) NUMBER OF DISRUPTIONS (T22)

Static traffic demand is available for the unused capacity of the survivable wavelength division multiplexing network. In dynamic traffic, the issue is optimized by the survivable wavelength division multiplexing network numeral linear encoding. This model created disturbance for the investigator [12]. New specifications in a network have maximum network capacity while minimizing the interruption of the auditor in the operating network. The technique of optimization eliminates disturbance. In certain respects, the disturbances impact the A1 to A5 alternative. Interruption must also be used as an option in the survivability inquiry.

3) LINK RESTORATION (T23)

If an optical fiber network link failure occurs, the network has been repaired.When connection get fails, unsuccessful upstream node sends a setup notification to the unsuccessful downstream node to fix the disparate route corresponding to the failed connection. This restoration procedure is termed as the restoration of the connection [14].

4) PARTIAL PATH RESTORATION (T24)

Upstream nodes convey the signal to the higher level when an error related situation occurs, while the lower level node starts sending a command of disassembly to the higher level. Incomplete route to complete the contact between the nodes is established as a consequence. This restoration technique is useful in a cost-effective way for the optical fiber network [15].

5) PATH RESTORATION (T25)

During a failure situation in optical fiber network, the message is sent to input point, as well as a command is sent to the output point for information. This type of exchange results in a continuous connection establishment because paths get exchanged after message delivery [16].

In the context of numerical survival study in the multiplexing wavelength division system, the researchers opted for the following five alternatives:

C. SERVICE AVAILABILITY (S1)

For current and future internet applications, requirements are needed. Service providers handle safe choices that range from full protection to no security. The emphasis on the approach to specific service delivery is relatable to secure pathway [17]. Network traffic is classified by service providers as: *full protection, no protection and best endeavor*. In the wavelength division multiplexing system, the availability calculated in service interruption is also a crucial alternative for survival.

D. SERVICE RELIABILITY (S2)

Reliability and availability are the two survival choices in the wavelength division multiplexing system. Both have contingent characteristics; the efficiency of the multiplexing network for wavelength segment is the likelihood over a time interval [18]. Reliability varies from one category to another that is displayed as non-operational (0) and fully functional (1). Maintenance cost of software is also relatable and connected to reliability and availability. Creating a more efficient and accessible alternative demands more investment.

E. RESTORATION TIME (S3)

It represents the restoring period of time and placed into operation. Link restoration is unidirectional; there are different wavelengths for each link communication. For each link, the restoration route is carried out by layered technique and phase that is classified in two layers [19]. Efficiency of re - installation is proportion of the number of connections restored after the interruption of the connection to fulfill the number of connections through the link.

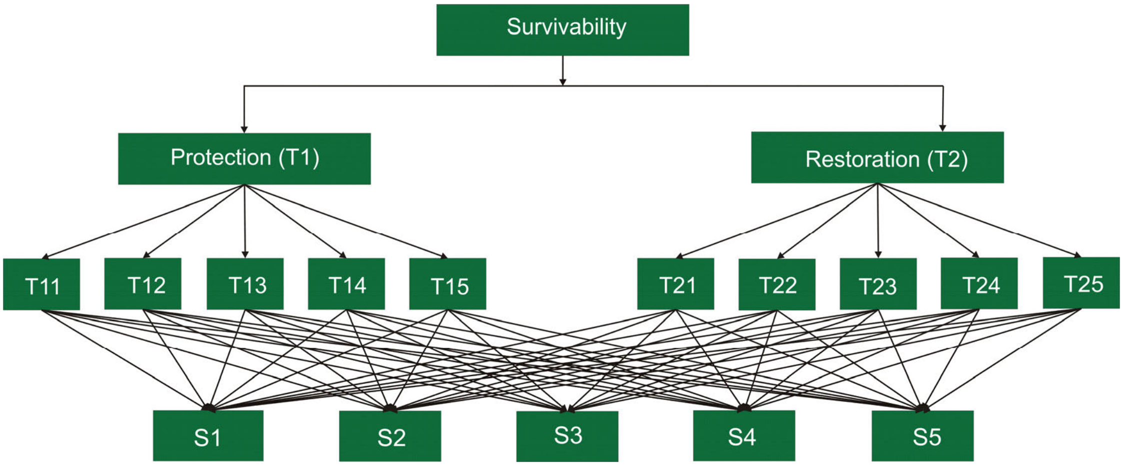

FIGURE 1. Hierarchy of survivability characteristics in WDM in optical fiber network communication.

F. SERVICE RESTORABILITY (S4)

It is often shown by research that more surviving capacity of network causes easy restoring mechanism and time [20]. Mesh-structured is the most commonly used network topology. Network errors typically occur attributable to the cutting of the optical fiber. A significant volume of data is transported by fiber cables. Cutting fiber can cause a huge loss of data that affects profitability. It is critical to create a survivable capacity and heavy resilience at the same time in a network. Restorability is therefore a significant alternative to predicting survivability.

G. DYNAMIC RESTORATION (S5)

This is an attribute that came in a situation of network security phase [21]. It does not give extra space for security in path but provides a security in network's extra ability to get optical network substitution when the problem happens. The excess capacity is much more objectively needed. Spare capacity is calculated by mapping the allocations of the wavelengths. For traffic congestion, the shortest paths are capable of obtaining the most desirable restoration paths.

The unified symmetrical method of hesitant fuzzy AHP and hesitant fuzzy TOPSIS analyses different features / alternatives, as described previously, and their effect on survival. In order to choose the features and design the appropriate network, the specialists have several choices that represent the implementation of the optical fiber network. In this inquiry, the researchers selected 5 projects as alternative and two attributes at first layer of hierarchy. After that, the authors have considered 10 various sub-factors at second layer of hierarchy (shown in figure 1) that is directly connected with different projects selected by the authors for the evaluation.

Figure 1 demonstrates the relationship of alternatives and characteristics in survivability; the researchers regarded S1 to S5 as the alternatives affecting survival in wavelength division multiplexing in contact with the optical fiber network. There are two layers of features; layer 1 has two attributes: T1 and T2.

IV. HESITANT FUZZY SETS BASED METHODOLOGY

Most real-world problems need decision-making solutions with several parameters to address them and render an informed decision. This category involves the option of survivability properties in the multiplexing of wavelength segment in fiber optic network communication properties. In MCDM approach, AHP is considered to be well-organized because it provides experts with an efficient solution [29]–[33]. In this methodology, matrix set theory of paired matrixes and result evaluation is associated. These pair-wise comparisons are seriously influenced by the judgments of specialists if there are different alternative solutions available. An integrated strategy comprising two MCDM approaches in which AHP gives the prioritization related results, and TOPSIS measures the evaluated results on various selected projects as experiments.

To achieve more precise checks, the paper implements the Hesitant-Fuzzy method. The decision-making method for multiple parameters has different complicated methods, but TOPSIS is deemed as the most efficient one in this league. It considers optimal, +ve and –ve results, providing a successful framework for it [11]. This type of situation needs some extra standard of measuring the real world situation and issues; hesitant factor of adopted approach gives this extra space to experts during measurement. Recent advancements in hesitant fuzzy set theories strongly believe in the growth of complexity [22].

Torra and Narukawa [23] are the founders of this hesitant theory that further gets updated by various researchers [24], in terms of relating and discussing about membership functions. Research has already extended the use of HFS. TOPSIS is widely used and adopted in various fields like cloud securities, as suggested by Wang and Chen [25]. The suggested solution allows vagueness and fuzziness of

TABLE 1. Standard list for HF-AHP.

Rank	Abbreviation	Linguistic Term	Triangular Hesitant-Fuzzy Number
10	AHI	Absolutely High Importance	(7 ,9 ,9)
9	VHI	Very High Importance	(5 ,7 ,9)
8	ESHI	Essentially High Importance	(3 ,5 ,7)
7	WHI	Weakly High Importance	(1 ,3 ,5)
6	EHI	Equally High Importance	(1 ,1 ,3)
5	EE	Exactly Equal	(1,1,1)
4	ELI	Equally Low Importance	(0.33,1,1)
3	WLI	Weakly Low Important	(0.2,0.33,1)
2	ESLI	Essentially Low Importance	(0.14, 0.2, 0.33)
1	VLI	Very Low Importance	(0.11, 0.14, 0.2)
0	ALI	Absolutely Low Importance	(0.11, 0.11, 0.14)

contextual definitions to be handled instantly. For the authentication of the proposed method, a descriptive illustration of stock selection is used, but Sun *et al.* [26] adopted this model as prediction theory model by comparing findings with other decision-making processes of multi criteria.

This research provided Hesitant-Fuzzy AHP for evaluating the ranking of various selected factors in hierarchy and then used the hesitant fuzzy TOPSIS approach to test these evaluated results in various projects. The adopted methodology works as follows:

Step 1: Develop a tree based structure by associating various relevant factors.

Step 2: Pair-wise comparisons among these features are performed with the aid of linguistic words in Table 1. A very higher scale is defined for experts to achieve more accurate results. T11 to T15 and T21 to T25 are the dependent alternatives in this MCDM process.

Step 3: Use Hesitant-fuzzy set [24], [34] for transformed numerical analyses. Let us consider T0 is the lowermost significance, and Tg to be the uppermost significance in the linguistic scale, and the statistical analyses are among Ti and Tj such that T0 $\leq$ Ti $\leq$ Tj $\leq$ Tg; calculate weights are described in formula (1).

$$OWA\left(a_1, a_2, \ldots a_n\right) = \sum\nolimits_{j=1}^{n} W_j b_j \tag{1}$$

Here, $W = (w_1, w_2, \ldots . w_n)^S$ represents the weight medium as $\sum_{i=1}^{n} W = 1$ and b_j takes significance equivalent to the highest of $a_1, a_2, \ldots . a_n$. Now, for assessing $\tilde{C}=(a, b, c, d)$ following formulas (2-5) used as:

$$a = min\left\{a_L^i, a_M^i, a_M^{i+1}, \ldots\ldots a_M^j, a_R^j\right\} = a_L^i \tag{2}$$

$$d = max\left\{a_L^i, a_M^i, a_M^{i+1}, \ldots\ldots a_M^j, a_R^j\right\} = a_R^j \tag{3}$$

$$b = \left\{\begin{array}{c} a_M^i, ifi+1=j \\ OWA_{w^2}\left(a_m^j, \ldots\ldots a_m^{\frac{i+j}{2}}\right), ifi+jiseven \\ OWA_{w^2}\left(a_m^j, \ldots\ldots a_m^{\frac{i+j+1}{2}}\right), ifi+jisodd \end{array}\right\} \tag{4}$$

$$c = \left\{\begin{array}{c} a_M^{i+1}, ifi+1=j \\ OWA_{w^2}\left(a_m^j a_m^{j-1}, \ldots\ldots a_m^{\frac{(i+j)}{2}}\right), ifi+jiseven \\ OWA_{w^2}\left(a_m^j, a_m^{j-1} \ldots\ldots a_m^{\frac{(i+j+1)}{2}}\right), ifi+jisodd \end{array}\right\} \tag{5}$$

Authors used equation (6&7) for assessing fist and second type weights as;

1st type weights (W1 $= (w_1^1, w_2^1, \ldots\ldots\ldots w_n^1)$):

$$w_1^1 = \eta_2, \quad w_2^1 = \eta_2\left(1-\eta_2\right), \ldots\ldots\ldots w_n^1 \eta_2 (1-\eta_2)^{n-2} \tag{6}$$

2nd type weights (W2 $= (w_1^2, w_2^2, \ldots\ldots\ldots w_n^2)$):

$$w_1^2 = \eta_1^{n-1}, \quad w_2^2 = \left(1-\eta_1\right)\eta_1^{n-1} \tag{7}$$

From the equation $\eta_1 = \frac{g-(j-1)}{g-1}$s, and $\eta_2 = \frac{g-(j-1)}{g-1}$ here g represents the most prioritized factor, and I and j represent the lowest and average high factors.

Step 4: For achieving the completion of ($\tilde{A}$), the following equations (8-9) were applied.

$$\tilde{A} = \begin{bmatrix} 1 & \cdots & \tilde{c}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{c}_{n1} & \ldots & 1 \end{bmatrix} \tag{8}$$

$$\tilde{c_{ji}} = \left(\frac{1}{cij_u}, \frac{1}{cij_{m2}}, \frac{1}{cij_{m1}}, \frac{1}{cij_1}\right) \tag{9}$$

Step 5: Now it's time to defuzzify the evaluated weights as d = (l, m1, m2, h) by applying following formulas

$$\mu_x = \frac{l + 2m_1 + 2m_2 + h}{6} \tag{10}$$

After that, there is a need to understand the consistency ratio by applying following equations:

$$CI = \frac{\gamma_{max} - n}{n-1} \tag{11}$$

$$CR = \frac{CI}{RI} \tag{12}$$

Here CI is the ratio of consistency and λmax portray the vector as well as n display the numerical weights f evaluation, additionally RI also display the random number in analysis part. Now, consistency ratio value must be lower then 0.1.

Step 6: Following equation (13) now used to assess geometric mean.

$$\tilde{r}_i = \left(\tilde{c}_{i1} \otimes \tilde{c}_{i2} \ldots\ldots \otimes \tilde{c}_{in}\right)^{1/n} \tag{13}$$

Step 7: Now its time to evaluate the most ranked factor weight by applying following formula.

$$\tilde{w}_i = \tilde{r}_1 \otimes \left(\tilde{r}_1 \otimes \tilde{r}_2 \ldots\ldots \tilde{r}_n\right)^{-1} \tag{14}$$

Step 8: Now as a next step defuzzify the values by (15).

$$\mu_x = \frac{l + 2m_1 + 2m_2 + h}{6} \tag{15}$$

Step 9: The defuzzified weights need to be normalized in form by (16).

$$\frac{\tilde{w}_i}{\sum_i \sum_j \tilde{w}_j} \tag{16}$$

With the Hesitant-Fuzzy TOPSIS, the next phase is to determine the best solution. TOPSIS allows specialists in the identification of the superlative solution for real-world problems as a commonly used MADM approach. Hwang and Yoon [27] proposed TOPSIS for the very first time. The positive results are most significant and effective one whereas negative results are most ineffective ones. The Hesitant-Fuzzy TOPSIS strategy is followed in this to demonstrate the proposed analysis study of survivability in wavelength division multiplexing in optical fiber network communication by prioritizing various factors of these standards. TOPSIS method uses an envelope strategy [38]–[43] for evaluating the difference or distance for H1s and H2s, As: $\boldsymbol{env}(\mathrm{H1s}) =$ [Tp, Tq] and $\boldsymbol{env}(\boldsymbol{H2s}) = [\boldsymbol{T}_p^*, \boldsymbol{T}_q^*]$, the distance is defined as:

$$\boldsymbol{d}\left(\boldsymbol{H1s}, \boldsymbol{H2s}\right) = \left|\boldsymbol{q}^* - \boldsymbol{q}\right| + \left|\boldsymbol{p}^* - \boldsymbol{p}\right| \tag{17}$$

Detailed steps are described as:

Step 10: Let us consider that there E experiments are selected as alternatives ($\boldsymbol{C} = \{\boldsymbol{C}_1, \boldsymbol{C}_2, \ldots\ldots \boldsymbol{C}_E\}$) as well as n factors for layer ($\boldsymbol{C} = \{\boldsymbol{C}_1, \boldsymbol{C}_2, \ldots\ldots \boldsymbol{C}_n\}$)

$\boldsymbol{e}_x$Describes the expertise of experts K

$\tilde{\boldsymbol{X}}^l = \left[\boldsymbol{H}^l_{S_{ij}}\right]_{E\times n}$ is considered as fuzzy matrix associating hesitant theory and $\boldsymbol{H}^l_{S_{ij}}$portray the experimental and factor based results produced by experts $\boldsymbol{e}_x$.

Different standards for TOPSIS methodology [35]–[37] is described as:

The standard are= {nothing, very bad, bad, medium, good, very good, perfect}.

$\boldsymbol{r}_1^1$ = between medium and good (bt M&G)
$\boldsymbol{r}_2^1$ = at most medium (am M)
$\boldsymbol{r}_1^2$ = at least good (al G)
$\boldsymbol{r}_2^2$ = between very bad and medium (bt VB&M)

The numerical analysis of theory is computed as [28]:

$\boldsymbol{env_F}$ (EGH (btM&G)) = T (0.33, 0.5, 0.67, 0.83)
$\boldsymbol{env_F}$ (EGH (amM)) = T (0, 0, 0.35, 0.67)
$\boldsymbol{env_F}$ (EGH (alG)) = T (0.5, 0.85, 1, 1)
$\boldsymbol{env_F}$ (EGH (btVB&M)) = T (0, 0.3, 0.37, 0.66)

Step 11: To associate the quantitative analysis of results $\left(\tilde{X}^1, \tilde{X}^2 \ldots\ldots \tilde{X}^K\right)$ that helps the author to portray a matrix as xij = [Tpij, Tqij]

$$\begin{aligned} \boldsymbol{T_{pij}} &= \boldsymbol{min}\left\{\boldsymbol{min}_{i=1}^K\left(\boldsymbol{maxH}^x_{t_{ij}}\right), \boldsymbol{max}_{i=1}^K\left(\boldsymbol{minH}^x_{t_{ij}}\right)\right\} \\ \boldsymbol{T_{qij}} &= \boldsymbol{max}\left\{\boldsymbol{min}_{i=1}^K\left(\boldsymbol{maxH}^x_{t_{ij}}\right), \boldsymbol{max}_{i=1}^K\left(\boldsymbol{minH}^x_{t_{ij}}\right)\right\} \end{aligned} \tag{18}$$

Step 12: αb portray the lower factor set as Sj effective affect as well as αc portray the lowest affective experiments.

Let us consider the positive HF set are denoted by $\tilde{\boldsymbol{C}}^+$ as well as equation is described as $\tilde{\boldsymbol{C}}^+ = (\tilde{\boldsymbol{V}}_1^+, \tilde{\boldsymbol{V}}_2^+, \ldots \tilde{\boldsymbol{V}}_n^+)$ where $\tilde{\boldsymbol{V}}_j^+ = \left[\boldsymbol{V}_{pj}^+, \boldsymbol{V}_{qj}^+\right](\boldsymbol{j} = \mathbf{1,2,3} \ldots .\boldsymbol{n})$ similarly the negative value is displayed as $\tilde{\boldsymbol{C}}^-$ and equation is denoted as$\tilde{\boldsymbol{C}}^- = (\tilde{\boldsymbol{V}}_1^-, \tilde{\boldsymbol{V}}_2^-, \ldots \tilde{\boldsymbol{V}}_n^-)$ where $\tilde{\boldsymbol{V}}_j^- = \left[\boldsymbol{V}_{pj}^-, \boldsymbol{V}_{qj}^-\right](\boldsymbol{j} = \mathbf{1,2,3} \ldots .\boldsymbol{n})$

Define $\tilde{\boldsymbol{V}}_{pj}^+, \tilde{\boldsymbol{V}}_{qj}^+, \tilde{\boldsymbol{V}}_{pj}^-$ and $\tilde{\boldsymbol{V}}_{qj}^-$ as:

$$\tilde{\boldsymbol{V}}_{pj}^+ = \boldsymbol{max}_{i=1}^K\left(\boldsymbol{max}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \alpha_b$$

and

$$\boldsymbol{min}_i = \mathbf{1}^K\left(\boldsymbol{min}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_c})$$

$$\tilde{\boldsymbol{V}}_{qj}^+ = \boldsymbol{max}_{i=1^K}\left(\boldsymbol{max}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_b} \tag{19}$$

and

$$\boldsymbol{min}_{i=1}^K\left(\boldsymbol{min}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_c})$$

$$\tilde{\boldsymbol{V}}_{pj}^- = \boldsymbol{max}_{i=1}^K\left(\boldsymbol{max}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_c} \tag{20}$$

and

$$\boldsymbol{min}_{i=1}^K\left(\boldsymbol{min}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_{b)}}$$

$$\tilde{\boldsymbol{V}}_{qj}^- = \boldsymbol{max}_{i=1}^K\left(\boldsymbol{max}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_c} \tag{21}$$

and

$$\boldsymbol{min}_{i=1}^K\left(\boldsymbol{min}_i\left(\boldsymbol{minH}^x_{S_{ij}}\right)\right)\boldsymbol{j} \in \boldsymbol{\alpha_{b)}} \tag{22}$$

Step 13: To display +ve and –ve results, the authors adopted the following equation (23-24) by explaining and $\boldsymbol{D}^-$), respectively.

$$\boldsymbol{D}^+ = \begin{bmatrix} \boldsymbol{d}\left(\boldsymbol{x}_{11}, \tilde{\boldsymbol{V}}_1^+\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{12}, \tilde{\boldsymbol{V}}_2^+\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{1n}, \tilde{\boldsymbol{V}}_n^+\right) \\ \boldsymbol{d}\left(\boldsymbol{x}_{21}, \tilde{\boldsymbol{V}}_1^+\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{22}, \tilde{\boldsymbol{V}}_2^+\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{21}, \tilde{\boldsymbol{V}}_n^+\right) \\ \boldsymbol{d}\left(\boldsymbol{x}_{m1}, \tilde{\boldsymbol{V}}_1^+\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{m2}, \tilde{\boldsymbol{V}}_1^+\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{mn}, \tilde{\boldsymbol{V}}_n^+\right) \end{bmatrix} \tag{23}$$

$$\boldsymbol{D}^- = \begin{bmatrix} \boldsymbol{d}\left(\boldsymbol{x}_{11}, \tilde{\boldsymbol{V}}_1^-\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{12}, \tilde{\boldsymbol{V}}_2^-\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{1n}, \tilde{\boldsymbol{V}}_n^-\right) \\ \boldsymbol{d}\left(\boldsymbol{x}_{21}, \tilde{\boldsymbol{V}}_1^-\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{22}, \tilde{\boldsymbol{V}}_2^-\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{21}, \tilde{\boldsymbol{V}}_n^-\right) \\ \boldsymbol{d}\left(\boldsymbol{x}_{m1}, \tilde{\boldsymbol{V}}_1^-\right) + & \boldsymbol{d}\left(\boldsymbol{x}_{m2}, \tilde{\boldsymbol{V}}_1^-\right) + & \ldots + \boldsymbol{d}\left(\boldsymbol{x}_{mn}, \tilde{\boldsymbol{V}}_n^-\right) \end{bmatrix} \tag{24}$$

Step 14: Closeness value is evaluated by following formula (24).

$$\boldsymbol{CS}\left(\boldsymbol{A}_i\right) = \frac{\boldsymbol{D}_i^+}{\boldsymbol{D}_i^+ + \boldsymbol{D}_i^-}, \quad \boldsymbol{i} = \mathbf{1,2}, \ldots .\boldsymbol{m} \tag{25}$$

where

$$\boldsymbol{D}_i^+ = \sum_{j=1}^{n} \boldsymbol{d}(\boldsymbol{x}_{ij}, \boldsymbol{V}_j^+) \quad \text{and } \boldsymbol{D}_i^- = \sum_{j=1}^{n} \boldsymbol{d}(\boldsymbol{x}_{ij}, \boldsymbol{V}_j^-) \tag{26}$$

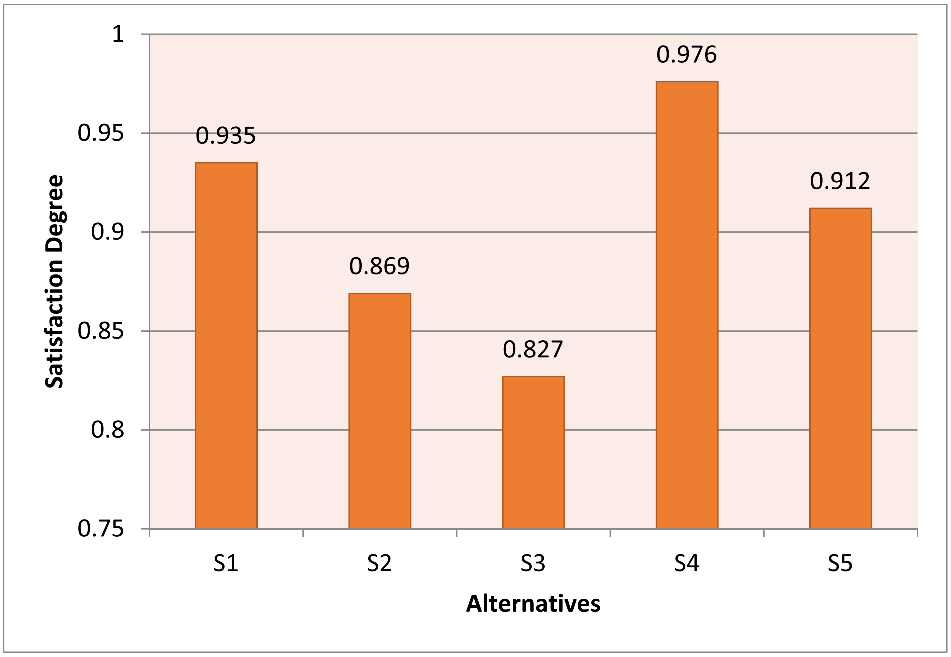

FIGURE 2. Graphical representation of the relative closeness for given alternatives.

Step 15: In the last step, we arranged the alternatives based on their closeness values.

Further, the actual evaluation of methodology has been drawn in the next section.

V. NUMERICAL ASSESSMENT AND OUTCOME

A. EVALUATION

Statistical study of wavelength division multiplexing network survival features in optical fiber network communication is a challenging task. As described previously in section 3 of paper, a numerical evaluation is the key step for achieving optimal survivability of optical fiber networks in the current era. Appropriate numerical analysis of features and alternatives provides the optical network manufacturers reliable and efficient performance. The authors have followed the Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS unified symmetrical approach to achieve the result. For the numerical analysis of characteristics, Table 1 and equations 1 to 9 are used.

Based on the use of equation (18), table 2 portrays the matrix values. As a next step, the evaluation of alternatives as experiments has been conducted by the authors in the next portion of section below. By using the formula (19 and 20), we generated the normalized form of matrix. Table 3 and 4 portray the values for various first layer attributes. Further, table 5 to 8 display the second layer values, cognition ratio values ad normalized values of the results. As a step of TOPSIS, the closeness value is evaluated by formula (24-25) and displayed as d_i^+ and d_i^-. The closeness degree (CC_i^+) is evaluated via formula 26 and portrayed in table 9. The graphical illustration of results is shown in figure 2. Further for evaluating effect of the characteristics on the survival of the multiplexing wavelength division network in the information transfer of the optical fiber network, five characteristic alternatives are chosen to determine the survival of the multiplexing wavelength division network; all are very sensitive for mathematical solution.

B. SENSITIVITY ANALYSIS

The sensitivity analysis has been used to check the effect of wavelength division multiplexing network survivability in contact with the optical fiber network. Table 10 reflects the sensitivity study. A graphical representation of results is shown in figure 3. The satisfaction degree ($\mathbf{CC}_i^-$) evaluated by numerical values of actual calculation (S1 to S5 taken as a constant), and by Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS approach, researchers calculated the ($\mathbf{CC}_i^-$).

C. A COMPARATIVE ANALYSIS WITH VARIOUS PREVIOUS METHODOLOGIES

Researchers enlisted a number of methods to further evaluate and to check the reliability and performance of the approach. Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS were employed in this article in analyzing the performance, proximity, or precision of the outcome achieved [28]. The researchers contrasted the findings with five different methods referred to in Table 11 and figure 4. Data anthology and data numerical analysis are similar to Hesitant-Fuzzy AHP TOPSIS in the standard AHP-TOPSIS, but no fluctuation is employed. The results obtained by means of the popular AHP-TOPSIS method are strongly interrelated (Pearson's coefficient of correlation 0.97256) with that of the F-AHP-TOPSIS quantity analyses and

TABLE 2. Pair-wise comparison matrix.

	T1	T2
T1	1.0000, 1.0000, 1.0000, 1.0000	3.0000, 5.0000, 7.0000, 9.0000
T2	0.1100, 0.1400, 0.2000, 0.3300	1.0000, 1.0000, 1.0000, 1.0000

TABLE 3. Hesitant-fuzzy pair-wise comparison matrix for protection.

	T11	T12	T13	T14	T15
T11	1.0000,1.0000, 1.0000, 1.0000	0.3400, 0.4800, 1.0000, 1.0000	0.3400, 0.4800, 1.0000, 1.0000	0.6900, 1.0000, 1.4400, 2.4700	0.6900, 1.0000, 1.4400, 2.4700
T12	0.0500, 0.1640, 0.2830, 1.0140	1.0000, 1.0000,1.0000, 1.0000	0.7000, 1.0000, 1.4000, 2.5000	0.3400, 0.4800, 1.0000, 1.0000	0.3400, 0.4800, 1.0000, 1.0000
T13	0.0345, 0.1656, 0.2256, 0.6200	0.0330, 0.0860, 0.1810, 0.4980	1.0000,1.0000, 1.0000, 1.0000	0.7000, 1.0000, 1.4000, 2.5000	0.7000, 1.0000, 1.4000, 2.5000
T14	0.0590, 0.2080, 0.3480, 1.2630	0.0480, 0.1570, 0.2710, 1.0250	0.0640, 0.2400, 0.4260, 1.2140	1.0000,1.0000, 1.0000, 1.0000	0.6900, 1.0000, 1.4400, 2.4700
T15	0.0540, 0.1330, 0.2810, 0.9480	0.0330, 0.1290, 0.2120, 0.7810	0.0520, 0.1590, 0.2970, 1.0250	0.0220, 0.0730, 0.1130, 0.5030	1.0000,1.0000, 1.0000, 1.0000

TABLE 4. Hesitant-fuzzy pair-wise comparison matrix for restoration.

	T21	T22	T23	T24	T25
T21	1.0000, 1.0000, 1.0000, 1.0000	0.6580, 1.5830, 1.1620, 1.6820	0.0540, 0.1330, 0.2810, 0.9480	0.0310, 0.0780, 0.1210, 0.390	0.0310, 0.0780, 0.1210, 0.390
T22	0.5920, 0.8580, 1.5190, 0.8380	1.0000, 1.0000, 1.0000, 1.0000	1.1930, 2.1590, 0.7570, 1.5520	1.6580, 1.5160, 1.9330, 1.5520	0.1490, 0.2760, 0.7230, 1.5090
T23	0.5890, 0.6940, 0.8790, 0.8380	0.4650, 0.6310, 0.8380, 1.6800	1.0000, 1.0000, 1.0000, 1.0000	1.9960, 1.3230, 1.5520, 0.7570	0.0760, 0.2180, 0.4550, 1.0310
T24	1.9390, 2.8430, 3.7310, 1.6800	0.5170, 0.6590, 1.1240, 0.8380	0.6440, 0.7570, 1.2540, 1.6880	1.0000, 1.0000, 1.0000, 1.0000	0.0350, 0.0970, 0.1980, 0.5130
T25	1.9780, 2.9530, 3.8750, 1.6820	0.6610, 0.9940, 1.4470, 0.7570	1.2380, 1.9150, 2.7740, 1.6800	0.7190, 0.8700, 1.1160, 0.7505	1.0000, 1.0000, 1.0000, 1.0000

TABLE 5. Hesitant-fuzzy pair-wise comparison matrix.

First Level Characteristic	Local Weights of First Level	Second Level Characteristic	Local Weights of Second Level	Overall Weights	Normalized Weights
T1	0.0280,0.1050, 0.1340,0.2430	T11	0.0290, 0.0950, 0.1360, 0.3250	0.0040, 0.0430, 0.1310, 0.8850	0.0840
		T12	0.0150, 0.0610, 0.0750, 0.2260	0.0060, 0.0400, 0.1570, 1.4620	0.0380
		T13	0.0130, 0.0440, 0.0590, 0.1730	0.0040, 0.0330, 0.1230, 1.1140	0.0700
		T14	0.0290, 0.0950, 0.1360, 0.3250	0.0040, 0.0220, 0.1050, 0.7110	0.0777
		T15	0.0150, 0.0610, 0.0750, 0.2260	0.0060, 0.0400, 0.1570, 1.4620	0.0924
T2	0.0290,0.0950, 0.1360,0.3250	T21	0.0130, 0.0440, 0.0590, 0.1730	0.0040, 0.0330, 0.1230, 1.1140	0.0530
		T22	0.0290, 0.0950, 0.1360, 0.3250	0.0080, 0.0620, 0.2480, 1.7320	0.2760
		T23	0.0290, 0.0950, 0.1360, 0.3250	0.0060, 0.0410, 0.1730, 1.4620	0.0900
		T24	0.0150, 0.0610, 0.0750, 0.2260	0.0060, 0.0400, 0.1570, 1.4620	0.1220
		T25	0.0130, 0.0440, 0.0590, 0.1730	0.0040, 0.0330, 0.1230, 1.1140	0.0972

Delphi AHP TOPSIS, the Hesitant-Fuzzy Delphi AHP TOPSIS [29], [30], [31], [33]. The reliability and performance of TOPSIS and Hesitant-Fuzzy AHP are strengthened and stronger than the other methods.

VI. DISCUSSION

The Hesitant-Fuzzy AHP-TOPSIS method was adopted to evaluate the effect and implications of characteristics on the survival of wavelength multiplexing by optical fiber grid

TABLE 6. Subjective cognition results of evaluators in linguistic terms.

Characteristics/ Alternatives	S1	S2	S3	S4	S5
T11	2.9100, 4.6400, 6.0000, 6.4500	1.4500, 3.0000, 4.9100, 5.4500	2.4500, 4.4500, 6.4500, 7.6500	0.9100, 2.4500, 4.4500, 5.6500	2.4500, 4.2700, 6.2700, 8.6500
T12	3.1800, 5.1800, 7.1000, 8.6500	1.4500, 3.0700, 4.9100, 5.6500	2.4500, 4.2700, 6.2700, 8.6500	3.9100, 5.9100, 7.8200, 8.6500	0.9100, 2.4500, 4.4500, 5.6500
T13	2.4500, 4.4500, 6.4500, 7.6500	0.9100, 2.4500, 4.4500, 5.6500	3.0000, 5.0000, 7.1400, 7.5100	2.1800, 4.0900, 6.1400, 7.5100	2.8200, 4.6400, 6.6400, 8.5100
T14	2.4500, 4.2700, 6.2700, 8.6500	3.9100, 5.9100, 7.8200, 8.6500	2.4500, 4.4500, 6.4500, 7.7300	3.5500, 5.5500, 7.4500, 8.7300	1.8200, 3.7300, 5.7300, 6.7300
T15	3.0000, 5.0000, 7.1400, 7.5100	2.1800, 4.0900, 6.1400, 7.5100	2.9100, 4.6400, 6.0000, 6.4500	1.4500, 3.0000, 4.9100, 5.4500	1.1800, 2.8200, 4.8200, 6.4500
T21	2.4500, 4.4500, 6.4500, 7.7300	3.5500, 5.5500, 7.4500, 8.7300	1.8200, 3.7300, 5.7300, 6.7300	1.6400, 3.5500, 5.5500, 6.7300	3.9100, 5.9100, 7.9100, 8.7300
T22	2.9100, 4.6400, 6.0000, 6.4500	1.4500, 3.0000, 4.9100, 5.4500	1.1800, 2.8200, 4.8200, 6.4500	2.0900, 3.7300, 5.7300, 6.4500	1.4500, 3.0000, 4.9100, 5.4500
T23	3.1800, 5.1800, 7.1000, 8.6500	1.4500, 3.0700, 4.9100, 5.6500	0.8200, 2.2700, 4.2700, 6.6500	3.0000, 4.8200, 6.8200, 7.6500	1.4500, 3.0700, 4.9100, 5.6500
T24	2.4500, 4.4500, 6.4500, 7.6500	0.9100, 2.4500, 4.4500, 5.6500	2.4500, 4.2700, 6.2700, 8.6500	3.9100, 5.9100, 7.8200, 8.6500	0.9100, 2.4500, 4.4500, 5.6500
T25	2.1800, 4.0900, 6.1400, 7.5100	2.8200, 4.6400, 6.6400, 8.5100	1.9100, 3.7300, 5.7300, 7.5100	2.5500, 4.4500, 6.4500, 8.5100	2.8200, 4.6400, 6.6400, 8.5100

TABLE 7. The normalized fuzzy-decision matrix.

Characteristics/ Alternatives	S1	S2	S3	S4	S5
T11	0.2420, 0.3970, 0.5470, 0.7430	0.4520, 0.6680, 0.7610, 0.8980	0.6110, 0.7720, 0.8560, 0.9450	0.4830, 0.6199, 0.7030, 0.8390	0.3460, 0.5530, 0.6640, 0.8170
T12	0.4830, 0.6199, 0.7030, 0.8390	0.3460, 0.5530, 0.6640, 0.8170	0.4370, 0.6360, 0.7360, 0.8580	0.2490, 0.4130, 0.5320, 0.7410	0.2420, 0.3970, 0.5470, 0.7430
T13	0.2420, 0.3970, 0.5470, 0.7430	0.4520, 0.6680, 0.7610, 0.8980	0.6110, 0.7720, 0.8560, 0.9450	0.6120, 0.8500, 0.9170, 0.9680	0.2420, 0.3970, 0.5470, 0.7430
T14	0.5740, 0.7250, 0.7920, 0.8960	0.2490, 0.4130, 0.5320, 0.7410	0.3460, 0.5530, 0.6640, 0.8170	0.4370, 0.6360, 0.7360, 0.8580	0.3340, 0.5240, 0.6180, 0.7800
T15	0.0398, 0.1000, 0.1920, 0.3840	0.4230, 0.6490, 0.7640, 0.8800	0.2420, 0.3970, 0.5470, 0.7430	0.6110, 0.7720, 0.8560, 0.9450	0.3800, 0.5740, 0.7220, 0.0820
T21	0.4830, 0.6199, 0.7030, 0.8390	0.3460, 0.5530, 0.6640, 0.8170	0.4610, 0.6570, 0.7650, 0.9050	0.5740, 0.7250, 0.7920, 0.8960	0.2490, 0.4130, 0.5320, 0.7410
T22	0.2490, 0.4130, 0.5320, 0.7410	0.2420, 0.3970, 0.5470, 0.7430	0.4370, 0.6360, 0.7360, 0.8580	0.0398, 0.1000, 0.1920, 0.3840	0.4230, 0.6490, 0.7640, 0.8800
T23	0.2420, 0.3970, 0.5470, 0.7430	0.4520, 0.6680, 0.7610, 0.8980	0.6110, 0.7720, 0.8560, 0.9450	0.4830, 0.6199, 0.7030, 0.8390	0.3460, 0.5530, 0.6640, 0.8170
T24	0.4830, 0.6199, 0.7030, 0.8390	0.3460, 0.5530, 0.6640, 0.8170	0.4370, 0.6360, 0.7360, 0.8580	0.2490, 0.4130, 0.5320, 0.7410	0.2420, 0.3970, 0.5470, 0.7430
T25	0.2420, 0.3970, 0.5470, 0.7430	0.4520, 0.6680, 0.7610, 0.8980	0.6110, 0.7720, 0.8560, 0.9450	0.6120, 0.8500, 0.9170, 0.9680	0.2420, 0.3970, 0.5470, 0.7430

TABLE 8. The weighted normalized fuzzy-decision matrix.

Characteristics/ Alternatives	S1	S2	S3	S4	S5
T11	0.0774, 0.1180, 0.1440, 0.1730	0.1330, 0.1680, 0.1840, 0.2080	0.0090, 0.0230, 0.0450, 0.0590	0.0090, 0.0230, 0.0450, 0.0590	0.0630, 0.0979, 0.1140, 0.1310
T12	0.0080, 0.0224, 0.0502, 0.1000	0.0090, 0.0230, 0.0450, 0.0590	0.1120, 0.1440, 0.1630, 0.1950	0.0090, 0.0230, 0.0450, 0.0590	0.0516, 0.0820, 0.0990, 0.1220
T13	0.0611, 0.1010, 0.1170, 0.1540	0.1120, 0.1440, 0.1630, 0.1950	0.0320, 0.0530, 0.0720, 0.0980	0.1120, 0.1440, 0.1630, 0.1950	0.0320, 0.0470, 0.0530, 0.0630
T14	0.0371, 0.0616, 0.0790, 0.1100	0.0320, 0.0530, 0.0720, 0.0980	0.0610, 0.0870, 0.1010, 0.1200	0.0320, 0.0530, 0.0720, 0.0980	0.0090, 0.0230, 0.0450, 0.0590
T15	0.0630, 0.0979, 0.1140, 0.1310	0.0610, 0.0870, 0.1010, 0.1200	0.0630, 0.0979, 0.1140, 0.1310	0.0610, 0.0870, 0.1010, 0.1200	0.1120, 0.1440, 0.1630, 0.1950
T21	0.0630, 0.0979, 0.1140, 0.1310	0.0630, 0.0979, 0.1140, 0.1310	0.1330, 0.1680, 0.1840, 0.2080	0.0630, 0.0979, 0.1140, 0.1310	0.0320, 0.0530, 0.0720, 0.0980
T22	0.0774, 0.1180, 0.1440, 0.1730	0.1330, 0.1680, 0.1840, 0.2080	0.0090, 0.0230, 0.0450, 0.0590	0.1330, 0.1680, 0.1840, 0.2080	0.0610, 0.0870, 0.1010, 0.1200
T23	0.0080, 0.0224, 0.0502, 0.1000	0.0090, 0.0230, 0.0450, 0.0590	0.0516, 0.0820, 0.0990, 0.1220	0.0090, 0.0230, 0.0450, 0.0590	0.0630, 0.0979, 0.1140, 0.1310
T24	0.0611, 0.1010, 0.1170, 0.1540	0.1120, 0.1440, 0.1630, 0.1950	0.0320, 0.0470, 0.0530, 0.0630	0.0320, 0.0530, 0.0720, 0.0980	0.1330, 0.1680, 0.1840, 0.2080
T25	0.0371, 0.0616, 0.0790, 0.1100	0.0320, 0.0530, 0.0720, 0.0980	0.0320, 0.0470, 0.0530, 0.0630	0.0320, 0.0530, 0.0720, 0.0980	0.0090, 0.0230, 0.0450, 0.0590

TABLE 9. Relative closeness of the alternatives.

Alternatives	d_i^+	d_i^-	Gap Degree of (CC_i^+)	Satisfaction Degree
S1	0.7510	0.0960	0.05960	0.9350
S2	0.7630	0.1550	0.15950	0.8690
S3	0.7740	0.1960	0.19550	0.8270
S4	0.7930	0.0450	0.04530	0.9760
S5	0.8150	0.0360	0.03260	0.9120

TABLE 10. Sensitivity analysis.

Experiments	Weights/Alternatives		S1	S2	S3	S4	S5
Exp-0	Original Weights	Satisfaction Degree (CC_i^-)	0.9350	0.8690	0.8270	0.9760	0.9120
Exp-1	T11		0.9100	0.8360	0.7990	0.9530	0.9680
Exp-2	T12		0.9320	0.9160	0.8760	0.9190	0.9460
Exp-3	T13		0.9910	0.9190	0.8820	0.9340	0.9530
Exp-4	T14		0.9500	0.8250	0.7830	0.9310	0.9480
Exp-5	T15		0.9760	0.8790	0.8180	0.9650	0.9230
Exp-6	T21		0.9270	0.8460	0.7920	0.9460	0.9660
Exp-7	T22		0.9560	0.8660	0.8260	0.9780	0.9850
Exp-8	T23		0.9140	0.8480	0.8250	0.9660	0.9730
Exp-9	T24		0.9580	0.8720	0.8270	0.9800	0.9870
Exp-10	T25		0.9360	0.8930	0.8430	0.9920	0.9160

contact with their alternatives. The findings of this investigation indicate the feasibility of the method proposed to check the impact of survival on the multiplex network of wavelength divisions. The basic criteria for survival are recovery and

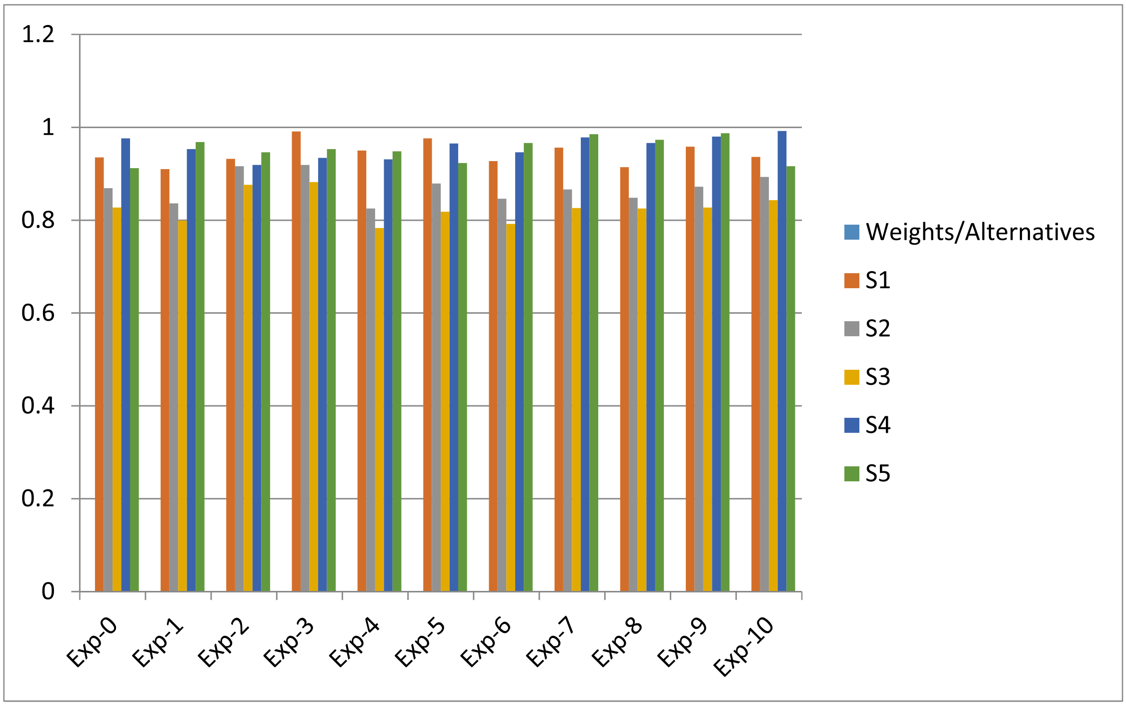

FIGURE 3. Graphical display of analysis.

TABLE 11. Comparison through classical fuzzy technique.

Methods/Alternatives	S1	S2	S3	S4	S5
Hesitant-Fuzzy AHP-TOPSIS	0.9350	0.8690	0.8270	0.9760	0.9120
Fuzzy AHP-TOPSIS	0.9380	0.8530	0.8120	0.9640	0.9780
Fuzzy ANP-TOPSIS	0.9260	0.8560	0.8260	0.9660	0.9730
Fuzzy-Delphi AHP-TOPSIS	0.9340	0.8530	0.8150	0.9660	0.9760

protection. The defense of fiber optics often requires time to secure the grid from disasters such as floods, earthquakes, etc. The proposed article associated 5 experiments as alternatives, two main factors on first layer and ten secondary layer factors related to optical fiber networks assessment and effectiveness. Literature survey in this context clearly establishes that optical fiber factors directly affect the transactions on the network. The characteristics' number of disturbances in the restore approach has been the first in this study.

The Hesitant-Fuzzy AHP approach and Hesitant-Fuzzy TOPSIS method have cooperation criteria, the criteria make the decision making complicated in the design phase of the multiplexing network of wavelengths. Different experts have different requirements according to their needs for the same framework.

Figure 1 defines features and alternatives of connective capability within the wavelength multiplexing networks in the hierarchy diagram for different alternatives and characteristics. There are interconnected characteristics. For the purpose of study of the effect of survival in the multiplexing wavelength distribution of optical-fiber communication, the researchers studied the characteristics and their dependence by means of the unified symmetrical method of Hesitant-Fuzzy AHP and Hesitant-Fuzzy TOPSIS. The main survival results of the multiplexing network for the wavelength division are:

- A systematic and exact priority list is given with the result of the characteristics that impact the survival of the multiplexing network in optical fiber based communication.
- This list of priorities would be an exact guide for experts in security and reconstruction, and enhancement of survival within the wavelength division multiplexing network.
- The highest ranked alternative is Service Restorability (S4) in investigated consequence of the survivability in wavelength division multiplexing in optical fiber network communication.
- The highest ranked characteristic is the number of disruption in the identified alternatives. It is very valuable for the specialists to take a restoration pathway for the data in wavelength division multiplexing network.

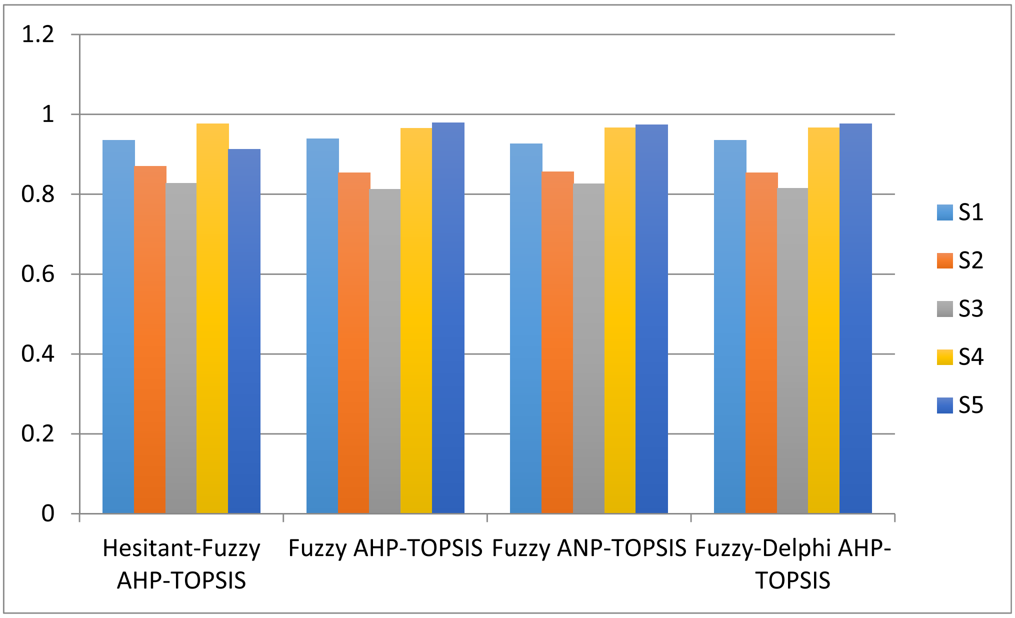

FIGURE 4. Graphical representation of comparison results.

- The study has institute five alternatives which impact the survivability in wavelength division multiplexing network. The weights of the survivability alternatives can be developed by implementing this quantitative analysis.

Strategy reduces the alternatives and contingent characteristics of the wavelength division multiplexing network. The selection of attributes and alternatives increases numerical and analytical complexity. The increased number study is made more acceptable by raising the characteristics and alternatives to two or three more steps. In various aspects and implementations, as needed by experts, the other methods to multi-criteria decision-making are also useful. The authors have, in conjunction with the results of this investigation, listed the results of decision making and compared it to the results of this study.

The support system for effective optical networks is survivability. This study was aimed at proposing a safer and more restored future growth of optical fiber. The detailed survival research must cover the enhanced technical features and the restoration method in a single manuscript. The present research combines all situations and is very helpful to preserve and restore the survival of the wavelength division multiplexing of optical fiber network.

VII. CONCLUSION

It is a crucial task for experts to manage transaction over optical fiber network associated with multiplexing as this market has vast failure situations that are caused due to various faults. It is a challenging task for experts and researchers to manage these faults because a single small fault can cause serious harm in network. Hence for tackling this type of situation, it is important to overcome the obstacles clearly. The proposed article aims to quantify the various factors and their impact on network by assessing different alternatives. As per this study, the most important priorities in the wavelength multiplexing network are the *Service Restorability (S4), and failure repair rate.* In addition, this study included a Unified Symmetrical approach in the form of Hesitant-Fuzzy to AHP and TOPSIS to classify the weights and alternatives derived from the empirical observation. For all those professionals who work in the area of optical communication networks, the final results of this study can be construed as conclusive, thus proving to be an authentic guideline. Future research should involve different characteristics in this area, as well as the analytical level should be improved to level two or three, based on the increase in the total number of alternatives.

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