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An Application of Multiple-Criteria Decision Analysis for Risk Prioritization and Management: A Case Study of the Fisheries Sector in Pakistan

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Abstract: In Pakistan, the fisheries sector is capable of making a significant contribution to the national economy. However, the proper and sustainable development of this sector is essential to its success, and we need to be aware of all the risks that it faces. At present, there is a dearth of comprehensive research that details, compares, and proposes applied measures to mitigate the risks facing the fisheries sector. Thus, this study is the first novel attempt to fill this gap. The data were collected through a survey and analyzed by multi-criteria decision analysis (MCDA). The study postulates that Sindh fisheries are affected by five main risk factors, namely technical, market, ecological, natural, and management. These risk factors are arranged from least to most significant. With regard to the performances of the main risk factors, management risk was ranked as the greatest risk, followed by ecological risk, natural risk, and technical risk. The findings of this study provide a road map for managerial decisions. Furthermore, this study also presents some potential limitations related to the scale of the data and analysis methods. Future studies may therefore use data collected on a large scale and alternative quantitative approaches.

Keywords: MCDA; sustainability; risk assessment; decision making; fisheries; AHP; IPA

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Citation: Mohsin, M.; Hengbin, Y.; Luyao, Z.; Rui, L.; Chong, Q.; Mehak, A. An Application of Multiple-Criteria Decision Analysis for Risk Prioritization and Management: A Case Study of the Fisheries Sector in Pakistan. *Sustainability* **2022**, *14*, 8831. https://doi.org/10.3390/su14148831

Academic Editors: Muntasir Billah, Golam Kabir and Subhrajit Dutta

Received: 10 June 2022
Accepted: 18 July 2022
Published: 19 July 2022

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1. Introduction

Fishery systems are complex and dynamic. They are usually characterized by variability, scarcity, uncertainty, etc., for which the term risk is used in fisheries management [1,2]. Risk is the perception of the possibility of negative occurrences [3]. The word began to appear in fisheries-management literature during the 1990s. The appearance of this term is usually attributed to three main factors. The first is that, in the past, several fisheries collapsed because of different factors [4,5]. The second is rising public awareness about the impact of industrial activities on the environment and human health [6,7]. The third is the increasing intervention of computing ability in scientific studies [8]. As a result, fisheries-risk-management studies began to appear in the published literature.

These studies employ various statistical methods to respond to a diverse array of problems [3]. Frequently, in fisheries, decision analysis is used to access risk. This analysis is carried out through statistical tools that have the ability to compute qualitative and quantitative data. Management plans are made by considering decision-analysis results against conflicting and compound objectives [9]. Multi-criteria decision analysis (MCDA) is a specialized decision-making procedure that may help fisheries make reliable and professional decisions [3,10]. The MCDA technique explicates numerous preferences against action substitute options and quantitatively ranks them. The principal method used for fisheries risk management that involves stakeholder decisions is the analytic hierarchy process (AHP) [11,12].

In the fisheries sector, MCDA has been widely used for planning, managing, making decisions, as well as selecting sites [13]. MCDA has used the AHP extensively for risk management in recent years. Measured by pairwise comparisons and based on expert judgments, the AHP assigns priorities and weights based on expert judgments [14]. The scales used in the AHP are based on human judgments of the importance of a particular component in relation to another. In uncertain environments, this method cannot account for factors related to imprecise and vague information. Fuzzy theory can be applied to supplement precise numbers or verbal expressions for evaluating measures, since they can be vague, inaccurate, and subjective [15]. The fuzzy set method involves mathematically presenting ambiguous and erroneous expressions in uncertain conditions or uncertain linguistic, and numerical terms, allowing explicit judgments to be made [16]. Sometimes, the fuzzy theory is described as a set theory that introduces subjectivity to solve these problems. Therefore, fuzzy AHP and importance performance analysis (IPA) techniques were used in a number of previous studies to analyze risk management and risk performance [17].

MCDA comprises a number of approaches, such as AHP, Analytic Network Process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Vise Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), Simple Additive Weighting (SAW), and aggregation operators [18]. For making decisions, Anand et al. [19] proposed the use of ANP, which can take both inner and outer dependencies into account. In an extension of this approach, Onut et al. [20] evaluated risk management related to the transportation industry using fuzzy TOPSIS. However, this approach is computationally complex and not suitable for managers who have to make quick decisions to solve real problems [21]. The main advantage of the AHP is its structured multi-attribute decision method, which reduces bias in the decision-making process.

In Pakistan, fisheries-risk-management studies received some attention from researchers after 2000. This because, in the past, the fisheries sector was not a priority sector, and meager efforts were directed toward its improvement [22]. However, this scenario has since changed, and there is a growing concern among public and private enterprises over the sustainable development of this sector [23]. The decline in capture fisheries and the overcapitalization of fishing fleets encouraged researchers to understand the risks faced by fisheries. Consequently, the recent scientific literature has begun to produce such studies. For instance, Mohsin et al. found the stock of *Parapenaeopsis stylifera* to be overexploited [24]. Similarly, Kaczan and Patil [25] declared that Pakistani fisheries are at risk of overexploitation. However, despite the fact that these studies indicate a variety of risks posed to Pakistani fisheries, they have many limitations. At present, there is a dearth of comprehensive research that details, compares, and proposes applied measures to mitigate the risks facing the fisheries sector. However, comprehensive management of this sector cannot be achieved without scientific studies ranking and prioritizing various kinds of risk. Thus, this study is the first novel attempt to fill this gap.

Generally, the studies described above do not examine more than one type of risk. Therefore, these studies lack the ability to portray the full picture of the risks facing fisheries. In addition, these studies are unable to rank risks in terms of priority for the more efficient and comprehensive management of this sector. Thus, this study fills this gap in the literature for the first time. By analyzing risk and performance in the fisheries sector, this study hopes to revive Pakistan's fishing industry. In addition, it demonstrates how to deal with these risks. Hence, this study aims to foster the sustainable development of fisheries in Pakistan in three ways: (1) determine which types of risk the fisheries sector faces in Pakistan; (2) prioritize risks for effective management; and (3) assess the management of different risks. The questions that will determine the achievement of these three objectives are as follows:

(1) Is there a wide range of risks hampering sustainable development in the Pakistani fisheries sector?
(2) In which order should the main and sub-risk factors be ranked?
(3) Which risk factors need to be addressed the most thoroughly in order to improve management performance?

The scope of this study includes identifying, ranking, and prioritizing the risk factors and sub-factors encountered by the fisheries sector in Pakistan. In order to meet the study objectives, as well as obtain answers to our questions, we collected relevant research and conducted a purposefully designed survey in Sindh, Pakistan. According to the current literature, the Pakistani fisheries sector faces five main risks, including market, technical, ecological, natural, and management risks. The following section includes a comprehensive overview of the main risks facing this sector.

2. Review of Literature and Theoretical Model

Below is a comprehensive description of the statistical procedures used in this study and the risks posed to Pakistani fisheries.

2.1. Fuzzy AHP and IPA

It is appropriate to use MCDA in the appraisal and determination of fisheries-management strategies. MCDA allows us to make informed decisions based on each contributing factor. In order to rank choices using multiple factors, MCDA has been used since the 1960s [25]. Researchers across a wide range of disciplines have used MCDA techniques. The AHP technique was developed for the first time by Saaty [21] in 1977. He subsequently revised the method many times. Researchers such as Teniwut et al. [26] used geographic analysis and AHP for determining information about seaweed, Vyas et al. [27] designed a special assessment tool to evaluate green construction, Giamalaki and Tsoutsos [28] employed geographic analysis and AHP to investigate photovoltaic systems, Havle et al. [29] applied AHP analysis in the transportation industry, and Al Mamun et al. [30] tried to investigate the quality of water by using fuzzy AHP methods. In order to provide an improved method for solving complicated issues, Dursun and Karsak [31] proposed the application of fuzzy theory.

The evaluation of human judgment can be simplified by using fuzzy sets that can be used to evaluate imprecise information in uncertain environments. In the MCDA process, linguistic items have proven to be effective replacements for crisp values as the model for judgment. Hence, fuzzy logic plays a crucial role in the decision-making process, and it is integrated into the AHP to provide more accurate results. AHP depends on rational assumptions by following stakeholders' focus on the priority ranking of risk factors. It hierarchically decomposes a selected problem into smaller decisions. Specifically, when one option is preferred over another by stakeholders, AHP algorithms rank options against various action choices quantitatively. This quality, the trade-off between objectives and the stakeholders, makes AHP and IPA an ideal statistical routine to be used in fisheries management, where the goal is pursued instead of optimization [3,13].

However, the statistical routines used in this study are not perfect. They use absurd scales, for example. Such scales are limited to measuring precise attributes. There are times when decisions do not make sense because they are mathematically impossible. Therefore, when used in this context, these techniques are not genuine. Models such as these are only evaluated when the output and input are directly related. Integrated models do not explicitly equate output and input, making them impossible to isolate. Additionally, the method fails to consider potential ambiguities and threats when making decisions, relying solely on stakeholders' discretion [32]. In addition, these approaches neglect to consider the precise magnitude of trade-offs [33]. Furthermore, ranking priority is also insufficient in these models [34]. However, these disadvantages do not mean that the results computed by these methods are not reliable; rather these statistical routines are famous all over the world for managing resources when multiple risks are involved. Therefore, by considering the advantages of these methods, we used AHP as well as IPA in this study.

2.2. Natural Risks

On many occasions in the past, natural disasters such as storms, tidal waves, torrents, and seismic activity severely damaged the fishing industry [35]. Additionally, the depletion of fish stocks and unsustainable harvesting are major risks in the midst of the decline of fisheries resources on high seas. To avoid stock collapse, some countries have enacted fishing-property rights through individual transferrable quotas. However, fisheries have been placed in jeopardy as a result of these conditions [36,37]. In coastal fishing countries, deteriorating oceanic climates also affect harvests, as oceanic weather changes are difficult to predict. For example, due to *El Niño*, the jack-mackerel fishery in Chile was threatened [38,39]. It is crucial to consider sea-level rises in light of climate change. The loss of mangroves is a direct consequence. People in Pakistan harvest food, fuel, and wood from mangrove forests. This area also houses 90% of the local shrimp population. Therefore, conserving mangrove forests is crucial for the prosperity of the shrimp fishery in Pakistan [40].

In natural-water bodies, temperatures fluctuate dramatically, which makes it difficult for fish to grow well. Both natural and man-made threats threaten the biodiversity of fishery species in Pakistan. Temperature variations, shifts in salinity, and wave action are responsible for the diffusion of anoxic waters from the depths. A lack of beach replenishment creates most of this man-made pressure. As a result, beach erosion accelerates and turbidity rises [41]. Despite the development of a small amount of experimental work, the Mexican shrimp fishery is extremely vulnerable to the steady rise in sea-surface temperatures [42]. Fisheries may be disrupted when large predators are present in the area [43]. As a result of ocean acidification, Alaskan marine organisms have a significant impact on local commercial harvests [44]. Featuring a comparative analysis of structural damage caused by earthquakes and tsunamis, Mabon and Kawabe [45] examined methods to deal with risks in the aftermath of disasters.

2.3. Ecological Risks

Fish populations have declined because of overfishing, water pollution, habitat destruction, and competition from exotic species [46]. Sustainable development has been at the heart of many fisheries-management plans, which include goals for habitats, endangered species, combinations of species, the diversity of species, ecological processes, and harvested species [47]. An example of salmon farms containing wild salmon infected with sea lice is given by Huang and Perrings [48]. According to Newman et al. [1], multispecies fisheries resources are at risk. The authors provided recommendations for avoiding them. By contrast, other studies assess the impact of genetic-population-structure changes, species interactions, and ecosystem changes on marine fishing from the perspectives of threats such as exotic-species invasion [1,49]. The fishery risk of habitat degradation has been decreased by using environmental offsets [50]. After their release in the natural environment, radionuclides exert effects on marine life, since they contaminate seawater. Some artificial disasters, such as radiation leaks, may also affect fishery products [51]. In a study on oyster recovery in the Hudson-Raritan Estuary, environmental pollution was found to pose a risk to aquaculture [52]. A fishery that is negatively affected by pollution may have very little or even no profitability. Several potentially hazardous inorganic fishery products have been produced as a result of polluted environments. The aquatic products consumed are generally contaminated by such products [53].

Certain fish-farming practices have been found to pose ecological risks. Enhancing fisheries resources might, for example, reduce the genomic variety under wild conditions [54]. Fishermen are also stated to have lost their fishing grounds to land-reclamation projects. Moreover, there has been a rapid sustainable development of coastal ports occupying large areas of the sea that are inhabited by fishermen [55]. Aside from increasing the demand for coastal resources, offshore resources, and ocean-carrying capacity, the sustainable development of islands is also placing increasing strain on islands' resources [56]. The effects of climate change on marine life have been related to the release of gases (greenhouse), such as CO_2. The stability and safety of marine fisheries are threatened by various factors related to man-made marine environments, such as eutrophication, toxic emissions, radioactive-waste disposal, oil and gas exploration, and improper waste disposal. The health-risk assessment of human exposure to aquatic products and the mercury content in aquatic products have long been a topic of focus for Chinese researchers [57,58]. Because of land pollution, the marine environment is deteriorating, and resources are being overexploited [59].

2.4. Market Risks

As a result of fishery products' sensitivity to price variations, the trade in aquatic products presents cross-price and own-price risk. Due to the large fluctuations in their incomes, fishermen face a high level of financial risk [60]. A range of factors, such as fluctuating market costs, the modification of rights to resources, unemployment losses, and asymmetric market information, contribute to the dynamic nature of market risks [3,61]. Fisheries risk can be categorized into four types: management, natural, market, and technical. Market risk is possible for the producers of seafood because of asymmetric information, disordered competition, and the fact that their production decisions are affected by market changes [62].

The constant increase in the price of fishery resources makes the operation and production of fishing more risky [63]. A lack of finances and investment, as well as the difficulty of circulating capital, further limit aquaculture's growth. Generally, most farmers do not tolerate risk well. Obtaining loans credit guarantees from financial institutions and is difficult. Risky industries do not attract private capital. In terms of government finance, this high-risk industry does not have a stable policy [64].

2.5. Technical Risks

Several commercial fish species are dependent on habitats for both physical shelter and productivity restoration. However, the excessive use of fishing gear can cause marine habitats to become highly stressed. Trawlers with rock-hoppers are able to fish efficiently even on uneven surfaces because they use bobbins on their trawls [65]. Equipment failure has been deemed a source of increasing uncertainty in fishing-vessel profitability by scholars [42]. According to Astles et al. [43], there is a risk of the oil or fuel associated with ships, engines, etc., accidentally spilling into the sea or air. The maintenance and emissions associated with boating can interfere with the process of fishing. Another common risk in aquaculture is the spread of infectious diseases [66].

Red tides, storm surges, and typhoons are among the natural risks faced by fishermen. Furthermore, they face challenges associated with diseases and management [53,67]. Some studies found the main risks associated with aquaculture are natural-disaster risks, social risks, and technological risks [68,69]. Fish growth can slow down, and fishes can even die out, due to invasive species or problems with breeding methods [70]. Marine fisheries are plagued by a lack of boats and poor-quality fishermen, leading to an increase in production risks. China is seeing an increase in deep-water-cage aquaculture. However, the system is not highly mechanized, automated, or industrialized. As a result, China's fishery industry lacks the ability to transform and upgrade [71].

2.6. Management Risks

The fisheries crisis affects not only fishing communities, but also management authorities, as argued by Cochrane [72]. It is crucial to obtain a thorough perception of fishermen's behavior to achieve effective fisheries management. If these skills are not acquired, many fisheries are at risk of collapse [73,74]. Of the US occupations with the highest worker compensation claims and work-related fatalities, fishing is the most dangerous [75,76]. Overfished marine fisheries can become resource-depleted and lose their profitability within a short period of time, despite their initial success. In a few studies, overfishing has been investigated [77]. The fishing industry also poses indirect risks. Contact with and without capture results in direct or indirect effects on habitats. Habitats can also be damaged directly when untamed species are encountered. In addition to lost fishing gear, there may be other risks, such as lost nets, warps, and otter boards [43].

3. Materials and Methods

This section provides details about the materials and methods used in this study.

3.1. Research Outline

There is a dearth of comprehensive research that details, compares, and proposes applied measures to mitigate the risks facing the fisheries sector. Therefore, this study examines, ranks, and prioritizes risks that this sector faces. Figure 1 presents the research framework of this study. A systematic approach was taken to conduct this study. We started by reviewing the literature to identify all the risks faced by the Pakistani fisheries sector. In addition, risk-response schemes were also identified. A risk hierarchy containing main and sub-risk factors was constructed using this information. Second, AHP was used to analyze the survey data regarding this risk hierarchy to determine the priority ranking for managing risks. Finally, IPA was performed in order to determine risk-management-improvement priorities based on perceived importance and satisfaction.

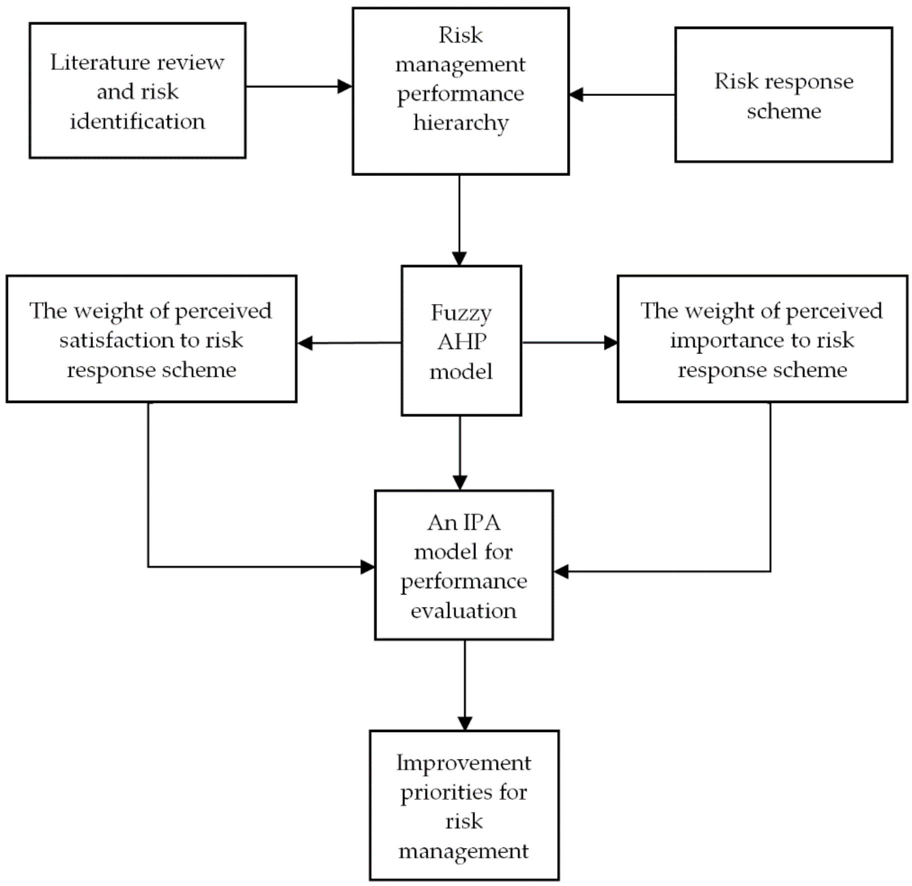

Figure 1. Research framework.

A hierarchy corresponding to risk management was constructed using pertinent published literature on its features and performance. There are two levels in this hierarchy. The first features five factors involved in risk management. The second features 18 sub-factors (Figure 2). Next, the data were analyzed for risk ranking using fuzzy AHP. Subsequently, by using the IPA technique, risk factors were prioritized for better management.

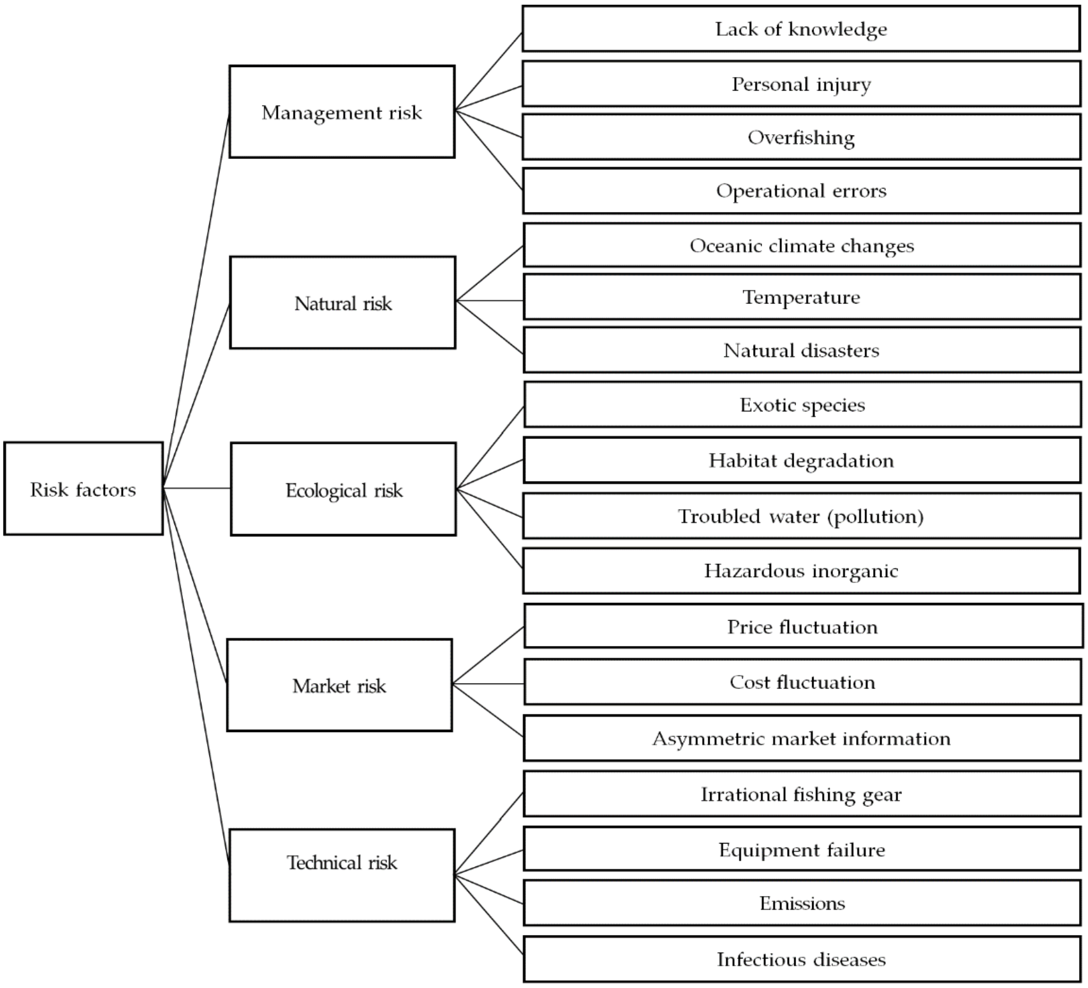

Figure 2. The two layers of risk factors in a hierarchical structure.

3.2. Data Acquisition

On the basis of existing studies, we designed a fuzzy AHP and IPA questionnaire. The questionnaire was first revised by two professors working in this field to ensure that there no important questions were missed. Next, it was reviewed by two experts in marine fisheries to check whether the statements were clear and understandable. This study sought to identify, prioritize, and analyze the risks faced by Pakistan's fisheries industry for more effective management. To achieve this, a structured questionnaire survey was carried out between 1 October 2021 and 31 December 2021 to collect data. Fishery experts in coastal districts of Sindh, Pakistan, viz., Karachi Central (128, 61% response rate), Thatta (77, 53% response rate), and Sujawal (42, 48% response rate) were contacted for their expertise. In consultation with fishery experts, we prepared a nine-point rating questionnaire [64] to ensure that no important question was missed. Details of those consulted are outlined in Table 1. The survey was conducted through face-to-face interviews and email, using the aforementioned purpose-designed questionnaire. In total, 247 complete questionnaires with a consistency ratio of less than 0.1 were collected.

Table 1. Characteristics of study subjects.

Category		Frequency	Percent
Status	Senior Research Fellow/Other	154	62.3
	Associate Research Fellow/Other	93	37.7
Marital status	Single	61	24.7
	Married	186	75.3
Gender	Male	208	84.2
	Female	39	15.7
Education	Ph.D.	43	17.4
	Masters	94	38.1
	Bachelor/Others	110	44.5
Working Experience	5–10 years	129	52.2
	More than 10 years	118	47.8
Region	Karachi Central District	152	61.5
	Thatta District	61	24.7
	Sujawal District	34	13.8
	Total	247	100.0

3.3. Data Analysis

Several survey participants were unable to complete the survey. We therefore calculated the response rate for each district. It was calculated by dividing the number of completed surveys by the total number of survey participants and multiplying by 100. Moreover, the Expert Choice 2000 program was also used to analyze the data using Fuzzy AHP and IPA routines.

3.3.1. Fuzzy AHP

An objective evaluation tool for decision-making, fuzzy AHP allows the determination and application of different criteria. The fuzzy theory can help compensate for the ambiguity, inaccuracy, and subjective nature of precise measures of verbal expressions [15]. Thus, an explicit judgment can be made using this method by showing uncertain or erroneous expressions numerically under unfavorable conditions, or mathematically in unfavorable terms [16]. Occasionally, the fuzzy theory is referred to as a subjectivity-based set theory. The analysis of risk-management and performance for marine fisheries has been undertaken frequently using AHP and IPA in the past [78,79].

The structure of this multi-attribute decision method reduces bias due to its structured approach. AHP can be used where measurements are insufficient, such as in modeling risk. Fuzzy AHP is widely applicable, since scales are used in place of measurements [80]. The data were analyzed by using AHP software, which uses the additive linear model and the axiom-independence method. Using pairwise comparisons, we calculated scores and weights for each option (risk type). Below, the fuzzy AHP analysis is presented.

We obtained 247 pairs of comparisons between risk factors and their corresponding sub-factors. An arithmetic mean (AM) is commonly used by researchers to reflect different subjects' preferences. However, this approach relies on very high values. The present study therefore used a fuzzy number to incorporate all choices. To represent subjects' choices, AM was estimated first [81,82]. Subsequently, based on the smallest data numbers and largest AM values, a fuzzy positive matrix was generated [83]. Next, a fuzzy AHP approach was used to calculate the weights of the risk factors.

We constructed the pair-wise comparison matrix A ($n \times n$) based upon n objectives, i.e., $A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}$ [84]. Moreover, a_{ij} values were interpreted on the basis of criteria presented in Table 2. This table illustrates the significance of ith objective versus jth objective based on its a_{ij} values when selecting the appropriate selection choice. If i and j are all 1, then a_{ii} must equal 1 and a_{ij} must equal $1/a_{ji}$. To find the sum of columns j of A, we divided each entry by the sum of columns j. As a result of this computation, A_w had one entry in each column, i.e., $A_w = \begin{bmatrix} \frac{a_{11}}{\sum a_{i1}} & \frac{a_{12}}{\sum a_{i2}} & \dots & \frac{a_{1n}}{\sum a_{in}} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ \frac{a_{n1}}{\sum a_{i1}} & \frac{a_{n2}}{\sum a_{i1}} & \dots & \frac{a_{nn}}{\sum a_{in}} \end{bmatrix}$ [84].

Table 2. Interpretation of a_{ij} values [85].

Scale	Interpretation (*i* as a Substitute for *j*)
1	Strongly preferred
2	Equal to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to very strongly preferred
7	Strongly preferred
8	Very strongly to extremely preferred
9	Extremely preferred

A column was generated by taking the average of row i of A_w vector C by using $C = \begin{bmatrix} c_1 \\ c_2 \\ \dots \\ c_n \end{bmatrix} = \begin{bmatrix} \frac{\frac{a_{11}}{\sum a_{i1}}}{n} & \frac{\frac{a_{12}}{\sum a_{i2}}}{n} & \dots & \frac{\frac{a_{1n}}{\sum a_{in}}}{n} \\ \dots & \dots & \dots & \dots \\ \frac{\frac{a_{n1}}{\sum a_{i1}}}{n} & \frac{\frac{a_{n2}}{\sum a_{i1}}}{n} & \dots & \frac{\frac{a_{nn}}{\sum a_{in}}}{n} \end{bmatrix}$ [84]. In this equality, ith objective is ranked according to its relative importance by C. It was ensured that the pairwise comparison matrix and sub-steps were consistent in their judgments. This process was performed in following steps. Step one: Compute A.C by using $A.C = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \begin{bmatrix} c_1 \\ c_2 \\ \dots \\ c_n \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix}$ [86]. Step two: Compute λ_{max} by using $\lambda \frac{1}{n} \sum_{i}^{n} {}_{-1} \frac{x_i}{c_i}{}_{max}$ [86]. The consistency ratio (CR) was computed by dividing the CI by a value obtained from a Random Consistency Index (RCI) table (Table 3). CR was estimated by using the formula $CR = \frac{CI}{RI}$ [84]. An acceptable CR value was 10% or less [84,87].

Table 3. Values of the matrix and corresponding RCI values [85].

Matrix Value	1	2	3	4	5	6	7	8	9	10
RCI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3.3.2. IPA

The IPA model was applied to analyze the performance of risk management. Based on its effect on a sector's performance, this matrix is frequently used as a statistical method to identify and rank the importance of various risk factors.

This grid can be used by a sector to identify the risk factors that need to be addressed rather than those that consume a significant volume of assets. The performance of the sector is relatively unaffected by these resources. Figure 3 illustrates an IPA two-dimensional grid made up of four quadrants. On the x-axis are the performance attributes. On the y-axis are the important attributes. Quadrant I is associated with high performance and high importance, expressed by the phrase 'Keep Up the Good Work'. Quadrant II is considered to be an 'Area for Improvement' due to its high importance but low performance. A 'Low Priority' attribute is defined by Quadrant III, which signifies a squat ranking of importance and performance. The characteristics of Quadrant IV are those with low importance but excellent outcomes, and are thus considered 'Possible Overkill'. In quadrants, I, II, and IV, these attributes would be more rationally employed as resources.

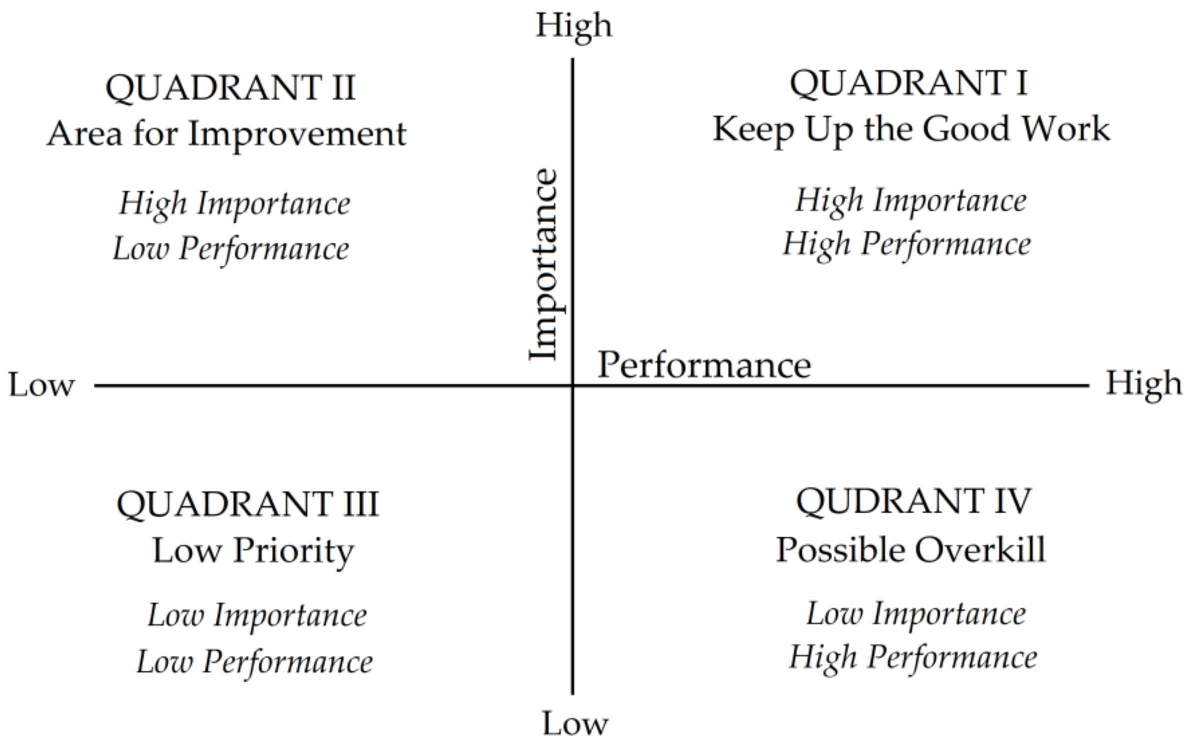

Figure 3. Demonstration of quadrant analysis of IPA.

4. Results

This section presents the results.

4.1. Description of Research Participants

A variety of the aspects of the research participants are illustrated in Table 1. The data were gathered from fishing professionals in order to identify and rank the risk factors. The details of the important aspects of the participants are as follows. The participants were divided into two categories: 'Senior Research Fellow/Others' (154 persons, 62.3% of the total), and 'Associate Research Fellow/Others' (93 persons, 37.7% of the total). The majority of the participants, i.e., 110 (44.5%) had Bachelor/other degrees, while 94 participants (38.1%) had Masters and 43 participants (17.4%) had Ph.Ds. The participants (129) with 5–10 years of work experience made up 52.2% of the group, while those with over 10 years of work experience (118) made up 47.8%. The participants' locations ranged from the Karachi Central District (44 individuals/66.7%) to the Thatta District (16/24.2%) and the Sujawal District (6/9%).

4.2. Main Risk Factors: Ranking of Importance and Priority (AHP Analysis)

The main risk factors are elaborated in Table 4, with their relative importance and priority ranking. According to their importance, form least to most, the main risk factors are ranked as follows: 'technical' (0.037), 'market' (0.067), 'ecological' (0.140), 'natural' (0.256), and 'management' (0.499).

Table 4. Main risk factors (ranking analysis of AHP).

Risk Type	Importance	Rank
Technical	0.037	5
Market	0.067	4
Ecological	0.140	3
Natural	0.256	2
Management	0.499	1

4.3. Risk Sub-Factors: Ranking of their Importance and Priority (AHP Analysis)

Figure 4 displays a graphical representation of the risk sub-factors, indicating their relative importance and priority ranking. From the least to the most important, the following sub-factors measured the management risk: personal injury (0.056), operational error (0.133), lack of knowledge (0.268), and overfishing (0.544) (sub-section a). In order, the most influential sub-factors of natural risk were 'temperature' (0.666), followed by 'oceanic climate changes' (0.237), and, finally, 'natural disasters' (0.098) (sub-section b). The ranking of the four ecological risk sub-factors, from the least to the most important, was as follows: exotic species (0.052), habitat degradation (0.108), troubled waters (pollution) (0.231), and hazardous inorganics (0.610) (sub-section c). The sub-factors of market risk, in ascending order of importance, were asymmetric market information (0.137), price fluctuation (0.282), and cost fluctuation (0.581) (sub-section d). The technical-risk sub-factors, ranked in ascending order of importance, were 'equipment failure' (0.053), 'infectious disease' (0.109), 'emissions' (0.217), and 'irrational fishing gear' (0.621) (sub-section e).

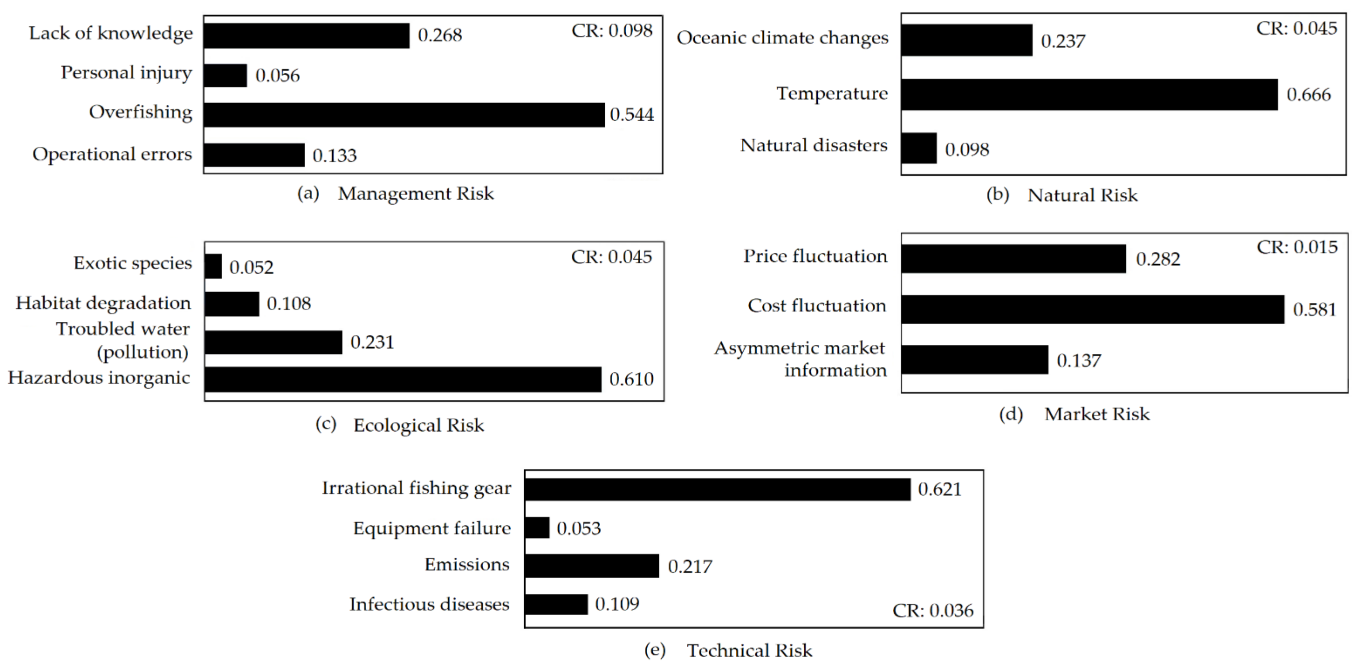

Figure 4. Risk-ranking analysis of AHP (sub-factors). See Section 5 for details on sub-risk types.

4.4. Main Risk Factors: Performance Analysis (IPA Analysis)

With regard to the performances of the main risk factors, according to the analysis, 'management risk' was ranked as the most significant factor, at 4.778, followed by 'ecological risk', at 4.000, 'technical risk', at 3.334, 'natural risk', at 3.333, and 'technical risk', at 2.888 (Table 5).

Table 5. Risk-performance analysis of IPA (main factors).

Risk Type	Performance	Rank
Management	4.778	1
Natural	3.333	4
Ecological	4.000	2
Market	2.889	5
Technical	3.344	3

4.5. Risk Sub-Factors: Performance Analysis (IPA Analysis)

The risk sub-factors of management risk performed as follows: "overfishing" (5.000), "operational errors" (4.000), "personal injury" (3.778), and "lack of knowledge" (2.778) (sub-section a). Overall, the sub-factors of natural risk performed as follows: 'oceanic climate changes' (3.667), 'natural disasters' (3.556), and 'temperature' (3.000) (sub-section b). The ecological risk sub-factors' performance was as follows: 'troubled waters (pollution)' (4.889), 'habitat degradation' (4.222), 'hazardous inorganic' (4.222), and 'exotic species' (4.000) (sub-section c). The market-risk sub-factors were in the following order of performance: 'price fluctuation' (3.000), 'asymmetric market information' (2.556), and 'cost fluctuation' (2.111), (sub-section d). Among the sub-factors of technical risk, irrational fishing gear placed first (4.333), emissions finished second (4.222), equipment failure came third (3.667), and infectious diseases placed fourth (3.556) (sub-section e) (Figure 5).

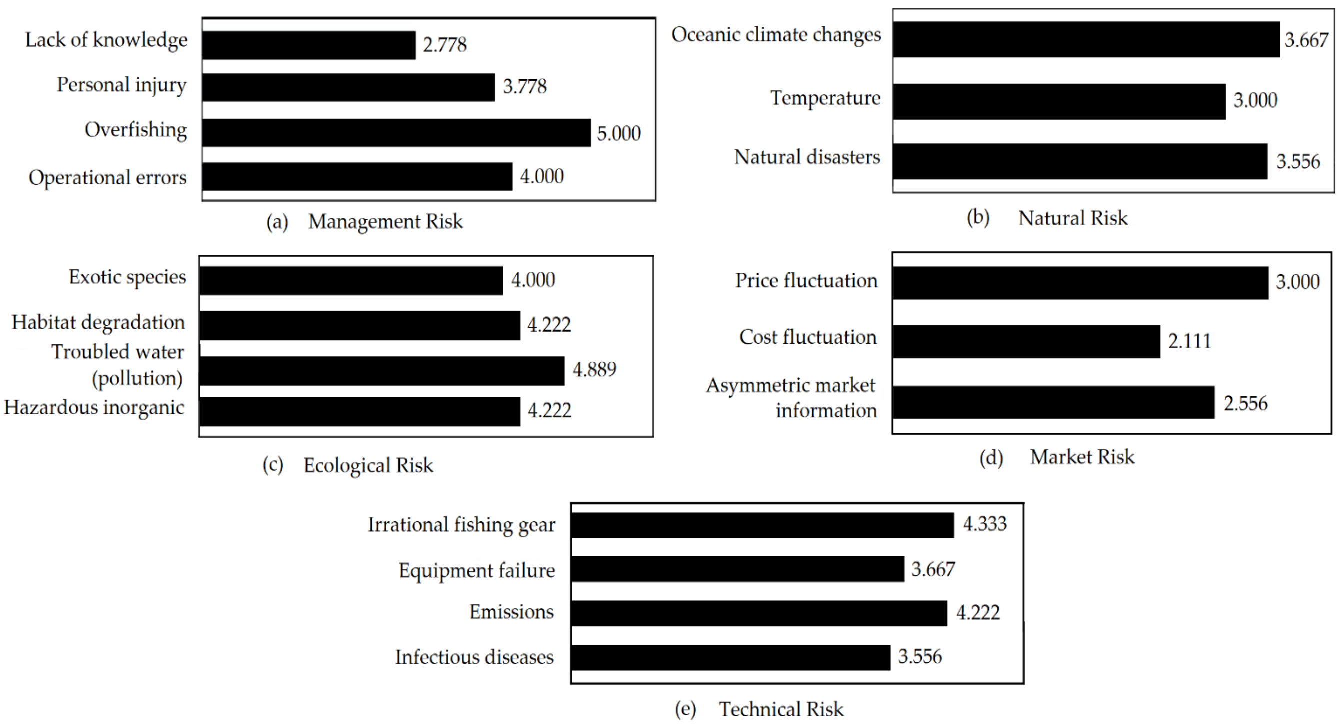

Figure 5. Sub-factor-risk (performance analysis of IPA). See Section 5 for details on sub-risk types.

4.6. Risk Management: An Improvement Assessment (IPA Analysis)

The results of the improvement assessment analysis are highlighted in Figure 6. A high degree of importance and performance was demonstrated by the following factors: overfishing, operational errors, and hazardous inorganic. Natural disasters, price fluctuations, cost fluctuations, asymmetric market information, equipment failures, and infectious diseases factors were highly important but performed poorly. Furthermore, factors that had low importance but performed highly were personal injury, exotic species, habitat degradation, troubled waters (pollution), irrational fishing gear, and emissions (Table 6).

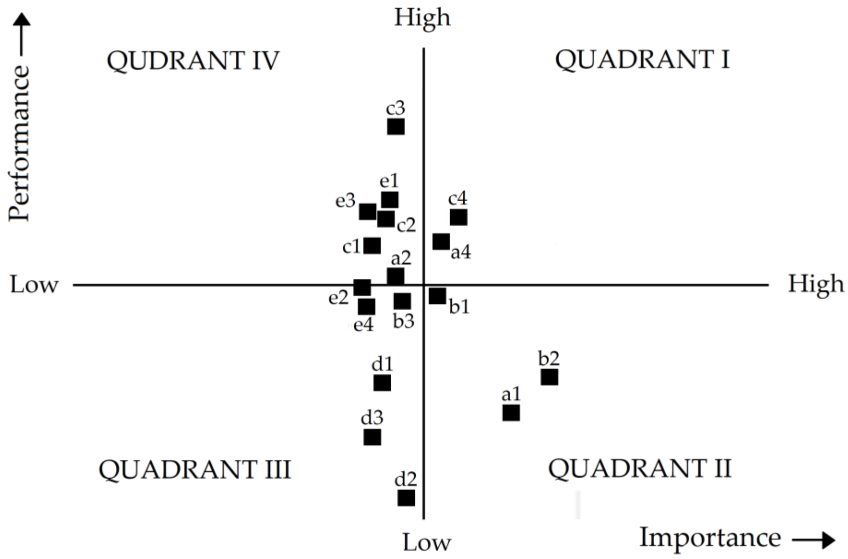

Figure 6. Matrix resulting from the IPA.

Table 6. Quadrant analysis of IPA.

Risk Type	Code	Factor	Importance (Weights %)	Performance (Weights %)	Quadrant
Management Risk	a1	Lack of knowledge	0.134	2.778	II
	a2	Personal injury	0.028	3.778	IV
	a3	Overfishing	0.271	5.000	I
	a4	Operational errors	0.066	4.000	I
Natural Risk	b1	Oceanic climate changes	0.061	3.667	II
	b2	Temperature	0.170	3.000	II
	b3	Natural disasters	0.025	3.556	III
Ecological Risk	c1	Exotic species	0.007	4.000	IV
	c2	Habitat degradation	0.015	4.222	IV
	c3	Troubled waters (pollution)	0.032	4.889	IV
	c4	Hazardous inorganic	0.086	4.222	I
Market Risk	d1	Price fluctuation	0.019	3.000	III
	d2	Cost fluctuation	0.039	2.111	III
	d3	Asymmetric market information	0.009	2.556	III
Technical Risk	e1	Irrational fishing gear	0.023	4.333	IV
	e2	Equipment failure	0.002	3.667	III
	e3	Emissions	0.008	4.222	IV
	e4	Infectious diseases	0.004	3.556	III

5. Discussion

This section presents a comprehensive discussion. Since management risk is the largest risk faced by the fisheries sector in Pakistan, this section focuses primarily on this risk and briefly explains the remaining risks. A general discussion and the implications of this study are presented at the end of this section.

5.1. Management Risks

The outcomes of this study are consistent with many previously published scientific works. For instance, many researchers found that the fisheries sector in Pakistan is exposed to uncontrolled overfishing [88,89]. Fishery resources in Pakistan must not be overexploited biologically. By controlling mesh sizes and implementing a ban on fishing during close seasons, this can be achieved [90]. In addition to overfishing, some studies also confirmed that various other factors, such as natural, ecological, market, and technical risks are also hindering the fisheries sector's sustainable development in Pakistan [91,92].

Fisheries-sector management issues in Pakistan are a result of inadequate laws and the improper implementation of policies [90]. Thus, it is necessary to determine how different kinds of risk can be handled. Risk management focuses on evading these risks, which is the easiest and most direct method, viz., the Precautionary Principle [93]. It is a logical and straightforward approach to avoiding risk [94]. This approach evaluates the expected risk involved in a decision in the context of costs and benefits. The decision is followed if the benefits outweighs the costs for a particular activity [95]. However, generally, factual costs and benefits for some specific management plans are impossible to predict accurately. Usually, the process of risk management is divided into two stages. The first stage involves the identification and characterization of the perceived risk, whereas the second stage comprises risk treatment [96,97]. Decisions for managing the risks posed by natural phenomena are expected to follow the Precautionary Approach [95]. The Precautionary Principle helps to manage risk in such circumstances. This principle suggests acting upon evidence that shows that such action is harmless [98]. Thus, the precautionary principle is the basis of most risk-management practices [99]. In addition, this principle contributes to the preservation of populations, as it reduces the risk of economic and population collapses [100,101].

Ideally, fisheries management should consider the biological as well as the economic aspects of fisheries equally [102]. In this regard, taking out insurance policies is an effective way to transfer risk [3]. Thus, as a result, Pareto efficiency occurs, whereby risks are transferred to another party, who can manage and bear them more effectively [103]. Furthermore, the insurance premium is also paid to the second party for its risk-bearing capability [3]. Insurance is rarely used to manage risk. Most developed countries use some form of this management practice [104]. Diversification and portfolio management can sometimes be used for fisheries' risk management. The fishery assets are placed into various groups. Selection is based on which groups deliver the best results [105]. Portfolio analyses are performed to identify the best group [3]. Diversification and portfolio management are widely applied to fisheries management around the world, as evidenced by a large body of research [75,106]. In order to manage fish-species harvesting, value-at-risk and risk-budgeting techniques can be used [86].

5.2. Market Risks

The price fluctuations involved in market risk are the reason that the revenue in fisheries can vary [2]. This risk makes business more difficult. Decisions related to resource allocation become difficult, such as investment in new processing facilities or fishing gear [3,107]. Diverse methods are recommended for dealing with price risk. These include enterprise integration, forward contracts, and market timing [108]. Contracts could be signed by buyers as well as sellers to fix prices in the future. This would reduce counterparty risk and ensure price stability. Alternatively, it is possible to hedge against price movements to eliminate this risk [109]. This risk can be reduced by integrating and consolidating the enterprise internally [110].

As a general rule, agricultural credit is considered to be an important means of coping with market risks. The impact of formal and informal credit is considered beneficial for risk management [111]. Credit can be used by fishermen to manage their risks when prices fluctuate [112]. Due to their low income and savings, small-scale fishers are more vulnerable to market-risk situations than large-scale subsistence farmers [113]. On the other hand, middle- and upper-scale subsistence fishers typically have a larger asset base and a more secure cash flow. Fishers from lower-class families often rely on informal sources to obtain credit, since they are easier to approach. A flexible credit system could minimize losses for small farmers [111]. The achievement of this goal also requires investment in aquaculture, improved fish processing, etc. [114]. The existence of asymmetric market information in the fishery market further suggests that an ecosystem-based management system helps mitigate market risks. New information and data are incorporated into the management system in a timely and effective manner, which can help to control this type of risk.

5.3. Natural Risks

Scholars have examined how insurance can be used to minimize the impact of natural risks in the ex ante and post-risk scenarios [111]. Fishermen are robustly protected from the ravages of oceanic climate change and have the ability to recover more rapidly after natural disasters [115]. However, the claim-settlement process is bureaucratic, and some fishermen were reluctant to submit claims because of ambiguous rules, a lack of awareness, the lengthy approval process, and high costs [116]. Some fisheries scholars subsequently argued that it is necessary to develop long-term strategies to revitalize livelihoods, such as climate-change-adaptation programs. To be successful, adaptation programs must be continuous over time, and they must incorporate plans for collaboration between governments, the private sector, and non-profit organizations, as well as ways of strengthening partnerships with stakeholders [117].

5.4. Ecological Risks

Pakistan needs to improve both its fisheries sustainability and its ability to add value to mitigate the market risks of its fisheries. In order to achieve this, its marine resources should be protected [22]. In order for Pakistan's fisheries sector to develop in the future, the ecosystem approach to fisheries must be integrated, argues Giri [114]. Unlike traditional fisheries management, which neglects the interactions between different species of fish, EAF considers the effects of fisheries on all species, including non-commercial species. Measures should be taken to rejuvenate the marine environment, conserve fragile ecosystems, and regulate destructive practices, as well as manage waste treatment and disposal, as recommended by the Sendai Framework [118]. Similarly, mangroves should be conserved and buffer green zones planted to mitigate habitat degradation. Detailed information on fishery and ecosystem performance can be gathered through an efficient and effective fisheries-information system [119]. Marine pollution in Pakistan was very poorly managed in the past. The Marine Pollution Control Board is one of the organizations that is currently trying to manage pollution. Pollution levels are still high, and they need to be lowered. It is imperative that all interested parties work together to develop environmental laws to prevent contamination from aquatic pollution [90].

5.5. Technical Risks

To reduce technical risks, technology needs to be developed to drive improvements in information and management methods. Satellite remote sensing, for example, is useful to obtain accurate information about wild fish stocks, monitor fishing activities, and provide consumers with information on fish products' origin and status [120]. Infectious diseases can be eliminated and marine fisheries can be improved with genetic modification and biotechnology [121]. A training program and support for fisheries management, ecosystems, and other ecosystem-based management principles can be helpful to mitigate technical risks [23]. Most technological problems are caused by poorly trained human resources. Therefore, training is necessary to enhance human skills and deal with this kind of risk. Fisheries in Pakistan are poorly controlled because there is a lack of coordination between various departments. All the technical challenges in this sector are based on this scenario. Pakistan's marine ecological environment has been severely damaged by destructive fishing. Therefore, proper government intervention and interdepartmental coordination are necessary in order to address this issue [90].

5.6. General Discussion

It was mentioned previously that multiple methods are used to rank management risks based on the MCDA. Based on their advantages, we chose the fuzzy AHP and IPA methods for this study. Fuzzy AHP was used to identify the main fisheries risks in Pakistan, and the IPA matrix was used to evaluate the risks to the management performance of fisheries. We removed the weight value when integrating and analyzing the fuzzy AHP and IPA data. Without a weight, AHP cannot be compared with other MCDA methods, fuzzy TOPSIS, VIKOR, etc. The published literature confirms this [17,30]. Therefore, this section presents a general discussion without comparing the methods used in this study with other MCDAs. The fisheries sector's sustainable development in Pakistan is severely hampered by insufficient harvest control. This sector features a number of requirements, according to Mohsin et al. [23], and governance structures are the prime determinants of the future environment. Effective management relies on scientific knowledge, continuous learning, and embedded monitoring processes [119]. Therefore, it is necessary to update aquaculture training and extension in Pakistan [114]. As part of a pilot program in Punjab, the Asian Institute of Technology has recommended that Pakistan use the "master trainer" approach. The training of trainers in neighboring countries that have advanced aquaculture industries would help to raise capacity in Pakistan. It would be helpful to further this process if intergovernmental and multinational organizations were to be reengaged to coordinate learning. The management of fisheries depends on preserving the ecosystems in which they operate. Efforts should be made to improve eco-based management outcomes in fisheries to achieve conservation and sustainable use [119]. To increase selectivity and reduce the ecological effects of commercial fishing, plans and harvest strategies that describe technical measures can be developed with the participation of small and commercial fishers [114].

A more effective approach to fisheries management can be achieved through this study's findings. The fisheries sector in Pakistan faces a wide range of risks. To address these risks, the national fisheries policy of 2007 is the foremost and most important approach. A variety of risks facing the fisheries sector are addressed in this policy. Additionally, overexploitation is addressed in Section 2. A of this policy [122]. However, it is still unclear how effectively this policy has been implemented. The Food and Agriculture Organization has a signed agreement with Pakistan that calls for improvements in the fisheries sector [123]. Public and private efforts have been noteworthy in this area, but many studies still indicate overfishing [124,125]. To ameliorate this situation, it is suggested that inter-departmental coordination be improved. In order to properly implement existing policies, managers should play a key role. Strict compliance with seasonal bans and the usage of smaller mesh sizes is required. A more detailed study of each risk type is also recommended, as well as policies to effectively manage these risk types. A bitter truth is that Pakistan lacks high-quality fishery research institutes. This sector cannot improve its performance and cope with the diversity of risks it faces without appropriate research and a suitable policy orientation. Thus, fisheries research needs to be promoted and institutions need to be strengthened [90].

5.7. Implications

The results of this study provide a road map for managerial decisions. For instance, the research findings indicate that management risk is the most significant risk posed to the fisheries sector in Pakistan. The findings also highlight other main types of risk and their corresponding sub-types. To design an effective management plan, it is imperative to understand the main and sub-risk types. Hence, several administrative implications can be drawn from these insights. By contrast, if risk management does not involve ranking and prioritization, it can easily fail. Moreover, this study identifies priority areas to enhance management performance. Therefore, it saves resources and, at the same time, encourages the use of resources in the most beneficial areas. By increasing the effectiveness of resource utilization, we can reduce the waste of resources. This research investigated risk factors and suggested some solutions to confront them. The efficiency of the fisheries sector would be boosted by policies designed to safeguard it from risks. In addition to developing Pakistan's fisheries, this will have a positive influence on the country as a whole. There are many ways to improve management, but finding suitable solutions is not straightforward. To enhance the fisheries sector's sustainable development, it is imperative to target the main and sub-risk contributing issues. By contrast, disorganized management will not produce favorable outcomes. Through pinpointing key areas of performance, this study attempts to provide comprehensive solutions to the management of risks that are not addressed in any previous studies.

6. Conclusions

To ensure the sustainable development of the fishing sector in Pakistan, this study examined the various risks it faces. In line with the research questions developed, the results revealed that this sector is affected by five main risk factors, namely technical, market, ecological, natural, and management, which were arranged from the least to the most significant. In terms of the performances of the main risk factors, according to the analysis, management risk was ranked as the greatest risk, followed by ecological risk, natural risk, and technical risk. These insights have several administrative ramifications that are both relevant and applicable. Alongside; they provide a road map for managerial decisions. Furthermore, this study also presents some potential limitations, as do most of the other published studies. For example, it is not possible to extrapolate the findings to other areas of Pakistan, as the data were mined only from Sindh. Future studies may therefore use data collected on a large scale. Moreover, to determine whether fisheries' risk management and performance are linked, it is imperative to determine how well risk management is performed over time. Research can be conducted in the future by using alternative quantitative approaches, focusing on management performance over the long term. Furthermore, the analytical tools employed were not perfect; this was another limitation of this study.

Author Contributions: Conceptualization, M.M. and Y.H.; methodology, Z.L. and A.M.; validation, Y.H. and L.R.; formal analysis, A.M.; investigation, Y.H.; resources, L.R.; data curation, M.M.; writing—original draft preparation, M.M. and Y.H; writing—review and editing, Z.L. and L.R.; visualization, Q.C.; funding acquisition, Y.H. and Q.C. All authors have read and agreed to the published this version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Ethical review and approval were waived for this study because the survey with human subjects consisted of non-invasive items.

Informed Consent Statement: Informed consent was obtained from all the subjects involved in the study.

Data Availability Statement: The data presented in this research are not publicly available due to participant privacy.

Conflicts of Interest: The authors declare no conflict of interest.

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