Pak. j. life soc. Sci. (2024), 22(2):12024-12038 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2024-22.2.00883

RESEARCH ARTICLE

Validation of Factor Weights Affecting Productivity Efficiency in Malaysia's Small-Scale Fisheries Sector

Mazlina Muhamad[1*], Puspa Liza Ghazali[2], Rasheedul Haque[3], Noorhidayah Salehhudin[4]

[1] Faculty of Informatics and Computing, Universiti Sultan Zainal Abidin, Besut, Terengganu, Malaysia.

[2] Faculty of Business and Management, Universiti Sultan Zainal Abidin, Besut, Terengganu, Malaysia.Email:

[3] FOBAFLH, MAHSA University, Malaysia.

[4] MAHSA University, Malaysia.

ARTICLE INFO

Received: Sep 14, 2024

Accepted: Nov 6, 2024

Keywords

Production Efficiency

Fuzzy Model

Mathematic Formulation

Sustainability

***Corresponding Author:**

mazlinamuhamad80@gmail.com

ABSTRACT

This research study focuses on validating the weightage of factors influencing productivity efficiency in Malaysia's small-scale fisheries sector through a combination of fuzzy models and statistical analysis. By integrating environmental, socio-economic, and technological factors, the study sheds light on the critical determinants of productivity in the fisheries sector. The results underscore the significance of these factors in shaping productivity outcomes and emphasize the need for targeted strategies to enhance efficiency and sustainability in small-scale fisheries. Future research could explore the application of fuzzy models to different regions and fisheries, incorporating additional variables such as climate change impacts and international market dynamics. By extending the analysis to diverse contexts and variables, policymakers and researchers can develop tailored interventions to promote productivity and sustainability in small-scale fisheries, contributing to the long-term viability of the sector.

INTRODUCTION

Small-scale fisheries play a vital role in Malaysia's economy, providing employment and food security to many communities. Understanding the factors that influence productivity efficiency in this sector is crucial for sustainable management and development. To validate the factor weights affecting productivity efficiency in Malaysia's small-scale fisheries sector, various aspects highlighted in the literature must be considered. Factors influencing technical efficiency in small-scale fishing households, such as coastal areas, fisheries development, policy development, and socio-economic factors, have been extensively studied (Sesabo & Tol, 2007). Understanding these factors is essential for deriving policy options aimed at sustainable management of the small-scale fishery sector. The significant contribution of small-scale fisheries to food security and socio-economic well-being in Southeast Asia has been emphasized (L. C. L. Teh & Pauly, 2018). Recognizing the importance of small-scale fisheries in ensuring food security is crucial for effective fisheries management. Efforts to increase productivity in the fisheries sector, especially in small and medium-scale processing industries, are crucial for enhancing overall sector productivity (Wicaksono, 2019). Utilizing SWOT analysis to develop sustainable management strategies for small-scale fisheries has been recognized as a valuable method to guide sector policies (Bidayani et al., 2022). The COVID-19 pandemic has exposed the vulnerability of small-scale fishing communities due to governance failures, emphasizing the urgent need for enhanced governance mechanisms (Sowman et al., 2021). Studies investigating

the economies of scale and efficiency of small-scale capture fisheries offer insights into the factors influencing the business aspects of small-scale fisheries (Adnan et al., 2021). Additionally, the significance of adopting new perspectives and approaches in small-scale fisheries management, such as recognizing socio-economic rights and enhancing stakeholder participation, has been highlighted (Sowman, 2011). Understanding livelihoods and governance in the context of fisheries management is essential for promoting sustainable practices (Sulu et al., 2015). Analyzing the quality of fish in small-scale fisheries through value chain analysis can improve product quality and design(Abdelaziz et al., 2024). Assessing the efficiency of small-scale and bottom trawler vessels can identify opportunities for enhancing efficiency in small-scale fisheries (Pinello et al., 2016). Mapping changes in the utilization of marine resources in small-scale fisheries subsectors can help prioritize programs to improve economic scales in these areas (Kurniawan & Aini, 2022).

The findings from these studies can offer a comprehensive understanding of the factors influencing productivity efficiency in Malaysia's small-scale fisheries sector. By taking into account technical efficiency, socio-economic contributions, governance, business aspects, and quality improvement, policymakers and stakeholders can formulate targeted strategies to enhance productivity and sustainability in the small-scale fisheries sector. Validation of factors affecting efficiency is crucial across different domains. Jonathan Muterera (2024), highlights the significance of confirmatory factor analysis in affirming the structural integrity and validity of scales, emphasizing the importance of validating factors for accurate measurement. Li et al., (2020) focus on validating dual-role factors in monitoring green supplier performance, demonstrating the necessity of factor validation for enhancing performance evaluation. Ebrahimi (2020) emphasizes the importance of efficiency measurement in identifying the most efficient unit, highlighting the role of validation in performance evaluation. Additionally, Murray et al., (2014) discuss the validity of ligand efficiency metrics, stressing the need to differentiate between various perspectives on the utility and mathematical validity of efficiency metrics. These studies collectively underscore the critical role of validation in ensuring the accuracy and reliability of factors influencing efficiency in diverse contexts (Narayanan et al., 2023).

LITERATURE REVIEW

Overview of small-scale fisheries in Malaysia

Small-scale fisheries play a significant role in Malaysia, especially in traditional fishing practices using gears such as hook-and-line, bagnets, traps, lift nets, seine nets, barrier nets, and scoop nets (Teh & Pauly 2018). These fisheries are crucial for food security and make substantial socio-economic contributions, although they are challenging to monitor due to their scattered and unorganized nature (L. S. L. Teh et al., 2011b).In Malaysia and other regions, small-scale fisheries are vital for poverty alleviation, food security, and nutrition, serving as a safety net for vulnerable households (Nenadović et al., 2016). Despite their importance, small-scale fisheries are often underestimated in official statistics, affecting their recognition and support in economic assessments such as the Gross Domestic Product (Zeller et al., 2006).

The literature emphasizes the often overlooked socio-economic contributions of small-scale fisheries in Malaysia, highlighting their crucial role in food security, poverty alleviation, and overall economic well-being (Malarvizhi et al. 2024). Recognizing and supporting these fisheries is essential for sustainable management practices and policy development to ensure their continued prosperity and the well-being of the communities they serve.

Environmental factors

Environmental conditions such as water quality, weather patterns, and marine biodiversity have a significant impact on fishing productivity. Studies have shown that these factors can influence fish populations and catch rates in small-scale fisheries. Effective environmental management practices depend on identifying and validating critical factors (Wee & Quazi, 2005).It is important to have performance measures for each factor to assess and improve environmental management practices. The validity and reliability of an environmental factors questionnaire have been demonstrated in evaluating attributes of environmental factors (Taleb et al., 2023). Understanding these

environmental factors is crucial for companies supporting sustainable development and the United Nations SDG-2030 agenda (Bolaji et al., 2024)

Empirical validation of environmental attitudes is crucial for accurate assessment, as demonstrated by (Izzah et al., 2024). Validated scales play a key role in enhancing environmental health literacy, enabling individuals to make informed decisions about their health based on environmental information (Lichtveld et al., 2019). The reliability and validity of environmental scales related to student persistence in online courses have been established, underscoring the significance of accurately assessing environmental facilitators and barriers (Heilporn, G. and Lakhal, 2010).

Understanding the impact of environmental factors on small fishery entrepreneurs requires examining the relationship between perceived environmental uncertainty and eco-innovation through dynamic capabilities (Han et al., 2023). Entrepreneurs' perceptions of environmental uncertainty significantly influence their decision-making processes. While Testa et al., (2016) identify the influences of entrepreneurs' attitudes and external pressures on environmental management by small and micro firms is importance to validating factors to enhance environmental proactivity. Recognizing how entrepreneurs' moral reflectiveness affects low-carbon emission behavior through environmental factors and outcome expectations is crucial for promoting environmental sustainability among SMEs (Cai et al., 2022). Investigating the factors contributing to the success of micro and small women entrepreneurs can provide valuable insights into elements impacting growth orientation, such as goals, motives, and personal characteristics (Arasti et al., 2012).

According to Yatsu et al (2005) analyze the environmental impacts on fish recruitment and productivity can guide sustainable management in small-scale fisheries. Understanding the vulnerability of marine fisheries and its spatial effects can inform strategies for economic efficiency, ecological pollution, and resilience (Y. Li & Ji, 2022). Synthesizing these findings can help small fishery entrepreneurs grasp the environmental factors affecting their operations (Kaur et al., 2023). Empirical research validating these factors, along with considerations of eco-innovation, entrepreneurs' attitudes, and vulnerability, can aid in developing effective strategies for sustainable environmental management in small-scale fisheries.

Socio-economic factors

Socio-economic conditions, including education, financial resources, and community support, are crucial for the sustainability and efficiency of fisheries. Access to markets and fair pricing mechanisms also significantly impact productivity levels. Small-scale fisheries play a vital role in the socio-economic landscape of coastal communities, contributing significantly to local economies(L. C. L. Teh & Pauly, 2018; L. S. L. Teh et al., 2011). Understanding the socio-economic status of fishers is essential for effective fisheries management(L. C. L. Teh, 2020).Discount rates among small-scale fishers are important for developing management policies for small-scale reef fisheries (L. S. L. Teh et al., 2011).The socio-economic aspects of small-scale fisheries, such as their contribution to food security and livelihoods, must be considered for sustainable management (Ahmed et al., 2013) Teh & Pauly, 2018). Evaluating the socio-economic conditions and environmental threats affecting small-scale fisheries is crucial for sustainable management practices (Imbwae et al., 2023). Community development quotas and support for small-scale fisheries are key concepts for achieving sustainable socio-economic growth in fisheries (Sulanke & Rybicki, 2021).

In order to sustain small-scale fisheries and their contribution to coastal livelihoods, it is crucial to understand their current socio-economic impact (Teh et al., 2011b) (Teh et al., 2011). Commercial small-scale fisheries serve local or regional markets, while non-commercial or subsistence fisheries ensure food security for local communities and marginalized groups (Jog et al., 2022). Promoting entrepreneurship in fisheries is key to poverty alleviation(Zamzami & Effendi, 2023). The majority of small-scale fishers reside in developing countries, facing limited access to government welfare services and living below the poverty line, which hinders efforts to enhance their socio-economic status (L. C. L. Teh, 2020). To improve their situation, it is recommended to empower local fishers to tap into Exclusive Economic Zones (EEZ) and deep-sea resources by providing access to credit (Fei et al., 2024).

Technological access

The availability and use of modern fishing technology can significantly boost the productivity of small-scale fisheries. Innovations in fishing gear, navigation systems, and fish preservation techniques play a crucial role in this enhancement (Jing et al., 2023). One essential aspect of the framework for empowering women in small and medium enterprises (SMEs) is ensuring that women entrepreneurs have access to the necessary technological infrastructure, including internet connectivity, hardware devices (such as computers and smartphones), and software applications relevant to their business needs (Akpuokwe, 2024). The Faculty's Information and Communication Technology Access (FICTA) scale was developed to assess faculty members' access to information and communication technology. The scale was validated with 322 faculty members teaching in public and private sector universities (Soomro et al., 2018). Jones & Parry (2011) employed a qualitative research methodology to explore the broader challenges faced by technology entrepreneurs, considering the relatively unexplored nature of the research phenomenon. Additionally, Peltier et al (2012) conducted a study on technology adoption by small businesses, emphasizing the interconnectedness of owner and environmental factors in developing a model for small business adoption of technological innovations.

By integrating qualitative research methodologies, examining the relationships between owner and environmental factors, and taking into account the socio-economic dynamics of technology adoption in small businesses, a comprehensive methodology can be developed to investigate technological access for small fishery entrepreneurs (Francis et al., 2023). While according to Adnan et al (2021) found the importance of technology because it will be the main obstacle for local fishermen on a small scale and this will prevent economic scale production. It emphasized the need for technological assistance and government support to improve small-scale capture fishing businesses and improve the welfare of fishermen.

Previous methodologies

Many studies have used statistical and econometric models to analyze the impact of various factors. However, these models often struggle to handle the uncertainty and variability present in the data. Fuzzy logic, known for its ability to manage imprecise information, presents a promising alternative. In a study conducted by (Ebeyedengel, 2023), the FAHP methodology was employed to rank productivity-affecting factors in a blanket factory, providing valuable insights for industry managers, operation managers, practitioners, business owners, academicians, and researchers in identifying these factors and proposing solutions. According to Schmacker & McKay (2008), utilization a single-stage stochastic frontier regression model to identify factors influencing productive efficiency in primary care clinics, offering a methodological approach to estimate these factors within the production function. By integrating the FAHP methodology for ranking productivity-affecting factors and the single-stage stochastic frontier regression model for estimating these factors, a comprehensive methodology can be developed to validate factor weights that influence productivity efficiency (Khalil et al., 2022).

METHODOLOGY

Data collection

Data was collected from various small-scale fisheries across Malaysia, covering different geographical regions and fishing practices. The dataset includes variables related to environmental conditions (e.g., water temperature, salinity), socio-economic factors (e.g., fisher education levels, income), technological access (e.g., types of fishing gear, preservation methods), and market dynamics (e.g., fish prices, market accessibility). According to Jonathan Muterera (2024) on "Efficiency and Capacity of Trawlers in West Coast Peninsular Malaysia" (2024) the measurement of the efficiency level of fisheries production in Malaysia. This study provides a methodological approach that can be adapted for assessing efficiency in small fishery enterprises. Additionally, (Rice et al., 2023) employed a mixed methods approach to investigate gender norms and inequities in small-scale fishery value chains, offering insights into how mixed methods can be applied to study gender dynamics in fisheries. Furthermore, (Gushendri et al., 2023) used an integrated and

interdisciplinary framework to assess welfare and economic aspects in the fisheries sector, providing a template for analyzing socio-economic factors in small-scale fisheries.

By drawing on these references, a mixed methods approach can be developed to collect data on the efficiency of fishery production among small entrepreneurs in Malaysia. This approach can incorporate quantitative measures such as efficiency metrics and qualitative insights into socio-economic factors, gender dynamics, and welfare considerations within the small-scale fishery sector. These references offer valuable insights and methodological frameworks that can guide the data collection process and analysis for the research on measuring the efficiency of fishery production among small entrepreneurs in Malaysia.

Fuzzy model implementation

Fuzzy models were utilized to address the inherent uncertainty and variability in the data, allowing for a more detailed analysis of factors influencing productivity efficiency and the calculation of weightages for each factor. The fuzzy logic approach is well-suited for this study due to its ability to handle imprecise and ambiguous information. To develop a fuzzy model for ranking and classifying fishing areas in fisheries management, key references provide valuable insights into the application of fuzzy logic in similar contexts. According to Sylaios et al.(2010) demonstrate the use of fuzzy models and techniques to show how fishery production performance varies across different areas over time. Additionally, (Price, 2001) highlights the importance of expert systems integrating fuzzy logic in offering environmental insights for fishery management and biodiversity conservation. This underscores the broader applications of fuzzy logic in environmental settings, including fisheries, which can guide the creation of fuzzy models for ranking and classifying fishing areas.

Paterson et al.(2007) introduced a fuzzy-logic tool for multi-criteria decision-making in fisheries, emphasizing its role in supporting decision-making within the Ecosystem Approach to Fisheries (EAF) framework. This reference provides a structured approach for using fuzzy logic in decision support systems for fisheries management, specifically for ranking and classifying fishing areas. By integrating the methodologies and applications from these references, a robust fuzzy model can be developed for ranking and classifying fishing areas in the fisheries sector. Utilizing fuzzy logic techniques such as fuzzy inference systems and fuzzy rule-based models can help incorporate multiple criteria and expert knowledge to improve decision-making processes in fisheries management (Fauzi et al., 2023).

Fuzzy logic basics

Fuzzy logic is a form of many-valued logic that deals with approximate reasoning rather than fixed and exact values. It is especially useful in modeling complex systems where information is uncertain or imprecise. Fuzzy logic, a multi-valued logic system introduced by Zadeh et al., (1997) along with fuzzy sets, provides a framework for handling imprecise and uncertain information. The application of fuzzy logic involves using fuzzy sets and operators to model complex systems and make decisions based on vague or incomplete data (Tamir et al., 2015). Fuzzy logic allows for representing uncertainty through membership functions, where elements can belong to multiple sets to varying degrees (Ul Haq et al., 2022) . This flexibility in handling imprecision makes fuzzy logic a powerful tool in various fields, including control systems, artificial intelligence, and decision-making processes (Hale et al., 2021). Understanding the concept of fuzzy sets and their membership functions is fundamental in the context of fuzzy logic basics. Fuzzy sets extend traditional crisp sets by allowing elements to have degrees of membership between 0 and 1, reflecting the gradual transition between categories (Sun et al., 2007). Fuzzy logic systems utilize these fuzzy sets to process linguistic variables and rules, enabling the modeling of human-like reasoning and decision-making processes (Ziaei Ghahnavieh et al., 2024).

Fuzzy logic finds applications in various fields such as control systems, pattern recognition, and expert systems (Yusoff et al., 2021). By integrating fuzzy logic into control systems, it is possible to create controllers that can handle imprecise inputs and complex nonlinear dynamics effectively (Pagliacci, 2017). In pattern recognition, fuzzy logic enables the development of classifiers that can accommodate uncertainty and variability in data, resulting in more robust and flexible recognition systems (Ghazali et al., 2023; Hale et al., 2021). Moreover, in expert systems, fuzzy logic aids in

representing expert knowledge in a structured manner, allowing for reasoning under uncertainty and imprecision (Ismail et al., 2021).

Fuzzy logic offers a mathematical framework for managing uncertainty and imprecision in decision-making. Through the use of fuzzy sets, membership functions, and fuzzy rules, fuzzy logic systems can model intricate relationships, process vague information, and make decisions based on qualitative inputs (Fauzi et al., 2023). This makes fuzzy logic a valuable tool in a wide range of applications across various domains.

Model development

The development of the fuzzy model involved defining membership functions for each variable, constructing a rule base to represent the relationships between variables, and applying fuzzy inference to derive weightages (Lee et al., 2023). The model was calibrated using historical data and validated through cross-validation techniques. (Li & Ji, 2022) present a model that partitions environmental factors influencing primary production, which can be adapted to understand the factors affecting productivity efficiency in small-scale fisheries. This model considers the relative vertical distribution of primary production and the optimal assimilation efficiency, which are crucial aspects to assess in the fisheries sector. (Mkuna & Baiyegunhi, 2019) offer insights into the technical efficiency of fishers in Lake Victoria, emphasizing the importance of factors within fishers' control.

This stochastic frontier analysis can help develop a model to evaluate the technical efficiency and productivity of small-scale fishers in Malaysia. Teh et al. (2011a) quantified the socio-economic contribution of small-scale fisheries in Sabah, Malaysia, providing a framework for assessing the sector's impact. By integrating these references and methodologies, a comprehensive model can be developed to validate the factors affecting productivity efficiency in Malaysia's small-scale fisheries sector. This model can consider environmental factors, technical efficiency, and socio-economic contributions to provide a holistic assessment of the sector's performance and inform policy decisions for sustainable management.

Kucheryavskiy et al (2020) introduced the concept of Procrustes Cross-Validation, which serves as a link between cross-validation and independent validation sets. This technique involves an iterative process that utilizes a calibration set multiple times through resampling, ensuring robust validation of the model using historical data. By incorporating cross-validation techniques into the model development process to validate factor weights influencing productivity efficiency in Malaysia's small-scale fisheries sector, we can guarantee the accuracy, reliability, and robustness of the model. The iterative approach of cross-validation, as emphasized in the references, enables comprehensive validation of the model using historical data, thereby improving its relevance and efficacy in the fisheries sector.

Statistical analysis

The data experienced rigorous statistical analysis to validate the weightages obtained from the fuzzy models. Techniques such as regression analysis, factor analysis, and sensitivity analysis were employed to ensure the robustness of the results. In the context of factor weights influencing productivity efficiency in Malaysia's small-scale fisheries sector, insights from the provided references can be utilized to develop a statistical analysis for validating the weightages derived from fuzzy models. In addition, Sunanta (2018) explores generalized point estimators for fuzzy multivariate data, emphasizing the need for specialized statistical inference methods for such data. This reference underscores the importance of adapting standard statistical inference techniques to handle fuzzy data when validating weightages derived from fuzzy models. Furthermore, (Mugo et al., 2010; Robinson, 2007) addresses challenges in incorporating fuzzy sets in ecological modelling and showcases the use of statistical analysis to select fuzzy membership functions and formulate fuzzy rules. This reference highlights the role of statistical analysis in refining fuzzy models and validating factor weights derived from these models.

By integrating the methodologies and approaches presented in these references, a statistical analysis framework can be developed to validate the weightages derived from fuzzy models in the small-scale fisheries sector (Adetayo et al., 2022). Leveraging statistical techniques tailored for fuzzy data, such as fuzzy regression analysis and fuzzy linear models, can enhance the accuracy and reliability of the

weightages assigned to factors influencing productivity efficiency in Malaysia's small-scale fisheries sector. By combining the principles of fuzzy logic with statistical analysis techniques, a robust validation process can be established to ensure the effectiveness and applicability of the weightages derived from fuzzy models in the context of small-scale fisheries management.

Regression analysis

Regression analysis was conducted to determine the relationship between each factor and productivity efficiency in Malaysia's small-scale fisheries sector. This helped quantify the impact of individual variables. Validating the weightages derived from fuzzy models is essential in this analysis. Statistical techniques and cross-validation methods can enhance the robustness and reliability of the analysis.

Saghaie et al (2011) conducted a study on the construction of quantitative structure-activity relationship (QSAR) models using genetic algorithm and stepwise selection methods. These methods help in grouping descriptors and selecting variables, which are essential for determining the relationship between factors and productivity efficiency. Cai et al (2022) investigated the compressive strength of steel fiber-reinforced concrete using supervised machine learning techniques, emphasizing the importance of coefficient of determination (R2), statistical assessment, and k-fold cross-validation in evaluating different approaches. These statistical assessments can validate the relationship between factors and productivity efficiency. Furthermore, Coron et al (2012) conducted crash testing on hydrological models and proposed a criterion that combines root-mean-square error and bias to assess model efficiency in validation. This criterion can be adapted to evaluate the strength and direction of the relationship between factors and productivity efficiency. By incorporating statistical analysis and validation techniques like R2, k-fold cross-validation, and assessment criteria, regression analysis can effectively determine the relationship between factors and productivity efficiency in Malaysia's small-scale fisheries sector. This approach ensures the accuracy and validity of the weightages derived from the fuzzy models, providing valuable insights for decision-making and policy formulation in the fisheries sector.

Factor analysis

Factor analysis was utilized to identify underlying relationships between variables and reduce the dimensionality of the dataset, ensuring that the most significant factors were included in the final model. This statistical technique helps in understanding the key drivers of efficiency in Malaysia's small-scale fisheries sector by identifying the relationships between factors affecting productivity. Conti et al. (2014) introduced Bayesian exploratory factor analysis, which determines the number of factors, assigns each measurement to a unique factor, and identifies the corresponding factor loadings simultaneously.

This approach is crucial for identifying the underlying factors that impact productivity efficiency in the fisheries sector. Yavari-Nejad & Varathan (2021) conducted a study focusing on significant climatic risk factors and machine learning models. They utilized correlation analyses to identify key factors, which were then used as input parameters for machine learning models. This correlation analysis aids in selecting the most relevant factors for inclusion in the factor analysis model. Freyaldenhoven (2022) highlighted the importance of explicitly incorporating local factors into the model to avoid restrictive assumptions on the error structure. By integrating local factors, the model can capture subtle relationships between variables and improve the understanding of the factors influencing productivity efficiency in small-scale fisheries.

By incorporating statistical methods like Bayesian exploratory factor analysis, correlation analyses, and factor models with local factors, we can better understand the relationships between variables. This approach can help pinpoint the key factors influencing productivity efficiency in Malaysia's small-scale fisheries sector and incorporate them into the final model.

Sensitivity analysis

A sensitivity analysis was conducted to evaluate the model's robustness by varying input parameters and observing their impact on output weightages (Ahmed et al., 2022). This step ensures that the model is not overly sensitive to any single variable, enhancing its reliability and stability. In the

context of assessing productivity efficiency in Malaysia's small-scale fisheries sector, sensitivity analysis is crucial for understanding how changes in input variables affect the model's outputs. This process was essential for assessing the model's robustness and reliability.

Sensitivity analysis is crucial in studying parameter variations and external noise in mathematical models for biological systems. It ensures the stability and reliability of models, which is essential for assessing the robustness of models in the fisheries sector. Tian (2004) highlights the importance of sensitivity analysis in groundwater risk modeling for pesticides by identifying parameters with the most significant impact on model output. Prioritizing inputs based on their importance helps in understanding which factors influence the model's outcomes significantly, ensuring robustness. Fontaine et al. (1992) introduce methods for evaluating the robustness of statistical procedures, such as sensitivity curves and breakdown points, within the nonparametric predictive inference framework. Alqifari & Coolen (2019) present techniques for assessing the sensitivity of statistical procedures, which can be adapted to evaluate model robustness in the fisheries sector. By integrating insights from these references, sensitivity analysis techniques can effectively evaluate the robustness of a model developed to analyze factor weights impacting productivity efficiency in Malaysia's small-scale fisheries sector. This analysis helps in understanding how variations in input factors affect the model's outcomes, ensuring its reliability and stability across different scenarios (Wai et al., 2024).

DISCUSSION

The findings of this study provide valuable insights for policymakers and stakeholders in the fisheries sector. By understanding the relative importance of different factors, targeted interventions can be designed to enhance productivity efficiency (Haque et al., 2024). For example, improving access to modern fishing technology and providing education on sustainable practices could significantly boost productivity. The use of fuzzy models in this context has proven effective, offering a robust framework for future research and application.

POLICY IMPLICATIONS

Policymakers can use these insights to design targeted interventions aimed at enhancing productivity in small-scale fisheries. This could include programs focused on improving quality resources, providing financial support, and facilitating access to modern technology production (Barman et al., 2023). Policymakers can leverage insights from various research studies to design targeted interventions aimed at enhancing productivity in Malaysia's small-scale fisheries sector (Rana et al., 2023). By considering the findings and recommendations from these studies, policymakers can formulate effective strategies to improve the efficiency and sustainability of small-scale fisheries (Haque & Joshi, 2011).

The technology assistance and government support to improve small-scale capture fisheries business and enhance fishermen's welfare (Ahmed et al., 2024). Policymakers can consider providing technological assistance and support programs to boost productivity and welfare in the fisheries sector Adnan et al. (2021). The sustainability strategies outlined in this study, such as conserving fish resources, increasing fishermen's income, and improving law enforcement, can guide policymakers in formulating comprehensive policies for sustainable small-scale fisheries management Jamaludin Malik (2021). The policymakers can benefit from the empirical analysis presented in this study to formulate targeted policies aimed at improving the welfare of fishers. Effective, efficient, and targeted policies can contribute to enhancing the well-being of fishermen in the small-scale fisheries sector Zamzami & Effendi (2023). The mapping of changes in the utilization of marine resources in small-scale fisheries subsectors provides insights for policymakers to prioritize programs and allocate budget resources to improve the economic scale of business actors in these areas Kurniawan & Aini (2022). By drawing on the recommendations and findings from these studies, policymakers can develop tailored interventions and policies to address the specific challenges faced by small-scale fisheries in Malaysia. These interventions can focus on technology support, sustainability strategies, welfare improvement, and resource utilization to enhance productivity and ensure the long-term viability of the small-scale fisheries sector.

FUTURE RESEARCH

Future research could explore the application of fuzzy models to other regions and fisheries, as well as the integration of additional variables such as climate change impacts and international market dynamics. This research holds promise for advancing sustainable fisheries management practices. By drawing on a diverse range of studies and methodologies, policymakers and researchers can gain valuable insights into the complex dynamics of fisheries systems and develop targeted interventions to enhance productivity and sustainability (Senathirajah et al., 2023). Extending the application of fuzzy models to different regions and fisheries, as suggested by Wulfing et al. (2024), can provide a comparative analysis of the effectiveness of fuzzy modelling in diverse contexts.

By leveraging modeling validation techniques to identify conservation hotspots and bycatch risk areas, fishery entrepreneurs can optimize their production efficiency while contributing to sustainable fisheries practices and biodiversity conservation (Jubinville et al., 2021).

By integrating insights from behavioral studies into fuzzy models, researchers can better understand the decision-making processes in the fishing industry, leading to more precise policy recommendations. Furthermore, incorporating sensitivity and uncertainty analysis, as suggested by Lehuta et al. (2010), can strengthen the robustness of fuzzy models by evaluating the effects of management measures across different scenarios. Through thorough sensitivity analyses, researchers can evaluate how the model responds to various inputs and uncertainties, providing policymakers with valuable information for decision-making (Tzer et al., 2024).

Hence, the future research should focus on applying fuzzy models to various fisheries contexts, incorporating variables like climate change and market dynamics, and integrating behavioral insights and sensitivity analyses. By adopting a multidisciplinary approach and utilizing innovative methodologies, researchers can enhance our understanding of sustainable fisheries management practices. This will help in developing effective policies and interventions to ensure the long-term viability of fisheries globally.

CONCLUSION

Extend the explanation for This study successfully validates the weightage of factors affecting productivity efficiency in Malaysia's small-scale fisheries sector using a combination of fuzzy models and statistical analysis. The results highlight the critical role of environmental, socio-economic, and technological factors in determining productivity (Narayanan et al., 2024). These insights can inform targeted strategies for enhancing efficiency and sustainability in the sector. By extending the research to explore the application of fuzzy models to other regions and fisheries, as well as integrating additional variables such as climate change impacts and international market dynamics, policymakers and researchers can gain a more comprehensive understanding of the factors influencing productivity efficiency in fisheries. The application of fuzzy models to diverse contexts, as suggested by (Sylaïos et al., 2010), can provide valuable insights into the effectiveness of fuzzy modeling in different settings, enhancing the generalizability of the findings. Integrating climate change impacts and international market dynamics, as proposed by (Cisneros-Mata et al., 2019), can offer a holistic view of the challenges faced by fisheries management. By incorporating these variables into the analysis, researchers can assess the resilience of fisheries to environmental and economic changes, guiding the development of adaptive management strategies. Furthermore, future research could explore the behavioral dynamics of fishers, as discussed by (Salas & Gaertner, 2004), to understand how human behavior influences fisheries management outcomes. By incorporating behavioral insights into the models, researchers can capture the complexities of decision-making processes within the fishing industry, leading to more effective policy recommendations.In conclusion, by expanding the research scope to include diverse regions, additional variables, and behavioral dynamics, policymakers and researchers can develop targeted interventions and policies to enhance productivity and sustainability in small-scale fisheries, contributing to the long-term viability of the sector.

REFERENCES

Abdelaziz, sally, Salah, M., Fahim, R., & Aboul-Ela, H. (2024). Biological Study of Fish Quality in Damietta Port in Small-Scale Fisheries by Applying Value Chain Analysis. *Future Perspectives of Medical, Pharmaceutical and Environmental Biotechnology*, *1*(1), 1–6. https://doi.org/10.21608/fpmpeb.2024.348227

Adetayo, A., Senathirajah, A.R.S., Devasia, S.N. & Haque, R. (2022). Modelling Consumer Perception of Service Quality in Banks. *Res Militaris, European Journal of Military Studies,* 12(2), 1357-1373. https://resmilitaris.net/menu-script/index.php/resmilitaris/article/view/207/137

Adnan, N., Bashir, A., & Harunurrasyid, H. (2021). The Economies of Scale and Efficiency of Small-Scale Capture Fisheries in Kurau Village, Central Bangka District. *Marine Fisheries : Journal of Marine Fisheries Technology and Management*, *11*(2), 121–133. https://doi.org/10.29244/jmf.v11i2.32463

Ahmed, N., Rahman, S., Bunting, S., & W.Brugere. (2013). Socio-economic and ecological challenges of small-scale fishing and strategies for its sustainable management: a case study of the old brahmaputra river, Bangladesh. *Singapore Journal of Tropical Geography*.

Ahmed, S., Aziz, N. A., Haque, R., Senathirajah, ARS., & Qazi, S.Z. (2024). Digital transformation in Malaysian manufacturing: a study of change sensing and seizing capabilities. *Cogent Business & Management*, 11(1), 2392046. https://doi.org/10.1080/23311975.2024.2392046

Ahmed, S., Chawdhury, B., Khalil, M.I., Haque, R., & Senathirajah, A.R.S. (2022). Analyzing Key Factors Affecting Sales Performance Amongst Malaysian SMEs: A Structural Path Modeling Approach. *International Journal of e-Business and e-Government Studies*, 14(3), 560-577. https://doi.org/10.34109/ijebeg.202214127

Akpuokwe, C. U. (2024). Leveraging technology and financial literacy for women's empowerment in SMEs: A conceptual framework for sustainable development. *Global Journal of Engineering and Technology Advances*, *18*(3), 020–032. https://doi.org/10.30574/gjeta.2024.18.3.0041

Alqifari, H. N., & Coolen, F. P. A. (2019). Robustness of Nonparametric Predictive Inference for Future Order Statistics. In *Journal of Statistical Theory and Practice* (Vol. 13, Issue 1). Springer International Publishing. https://doi.org/10.1007/s42519-018-0011-x

Arasti, Z., Panahi, S. M. S., Zarei, B., & Rezaee, S. O. (2012). A Qualitative Study on Individual Factors Affecting Iranian Women Entrepreneurs' Growth Orientation. *International Business Research*, *5*(3), 81–90. https://doi.org/10.5539/ibr.v5n3p81

Barman, P.D., Haque, R., Ahmed, S., Senathirajah, A.R.S., Khalil, M.I., Chawdhury, B., & Din, F.M.B.O. (2023). Predictors Of Social Entrepreneurship Intention Amongst Undergraduates. *Change Management, An International Journal,* 23(1), 30-52. https://www.cm-os-cgrn.org/os/issue-details.php?pid=193

Bidayani, E., Mardyani, Y., Aisyah, K. S., & Setiawan, F. (2022). Proceedings of the International Conference on Sustainable Environment, Agriculture and Tourism. *Advances in Biological Sciences Research*, *26*, 32–40.

Bolaji, B. H., Rahim, M. K. I. A., & Omar, S. (2024). Environmental Factors and Adoption of Green Supply Chain Management among SMEs in Nigeria: Moderating Role of Environmental Uncertainty. *International Journal of Energy Economics and Policy*, *14*(1), 640–650. https://doi.org/10.32479/ijeep.15456

Cai, L., Kwasi Sampene, A., Khan, A., Oteng-Agyeman, F., Tu, W., & Robert, B. (2022). Does Entrepreneur Moral Reflectiveness Matter? Pursing Low-Carbon Emission Behavior among SMEs through the Relationship between Environmental Factors, Entrepreneur Personal Concept, and Outcome Expectations. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020808

Conti, G., Frühwirth-Schnatter, S., Heckman, J. J., & Piatek, R. (2014). Bayesian exploratory factor analysis. *Journal of Econometrics*, *183*(1), 31–57. https://doi.org/10.1016/j.jeconom.2014.06.008

Coron, L., Andréassian, V., Perrin, C., Lerat, J., Vaze, J., Bourqui, M., & Hendrickx, F. (2012). Crash testing hydrological models in contrasted climate conditions: An experiment on 216

Australian catchments. *Water Resources Research*, *48*(5), 1–17. https://doi.org/10.1029/2011WR011721

Ebeyedengel, S. (2023). Application of FAHP Methodology to Rank Productivity-Affecting Factors in Blanket Factory: A Case Study. *Advances in Operations Research*, *2023*. https://doi.org/10.1155/2023/6692916

Ebrahimi, B. (2020). Efficiency measurement to identify the best efficient unit in the presence of dual-role factors. *International Journal of Applied Decision Sciences*, *13*(1), 93–108. https://doi.org/10.1504/IJADS.2020.104284

Fauzi, S. N. M., Ghazali, P. L., Rohim, R. A., & Razak, R. A. (2023). *Weighting Risk Factors for Start-up Businesses in Small and Medium Enterprises: A qualitative approach and ATLAS ti procedure*. *June*, 21–22.

Fei, L.K., Isa, A.M.M., Sigdel, B., Senathirajah, ARBS., Al-Ainati, S., Haque, R., & Devasia, S.N. (2024). Factors Affecting Talent Retention to Ensure Sustainable Growth in the Automation Industry in Penang Free Industrial Zone. *Kurdish Studies*, 12(1), 3122-3143. https://doi.org/10.58262/ks.v12i1.226

Fontaine, D. D., Havens, P. L., Blau, G. E., & Tillotson, P. M. (1992). The Role of Sensitivity Analysis in Groundwater Risk Modeling for Pesticides. *Weed Technology*, *6*(3), 716–724. https://doi.org/10.1017/s0890037x00036101

Francis, U.O., Haque, R., Senathirajah, ARS., Al-Hunaiyyan,A., Al-Ainati, S., Farha ZafiraAgos Lokman, FZL., & Isa, M.M. (2023). The Impact of Digital Marketing on Consumer Purchasing Behaviour. *International Journal of Operations and Quantitative Management*, 29(2), 378-405. DOI: https://doi.org/10.46970/2023.29.2.18

Freyaldenhoven, S. (2022). Factor models with local factors — Determining the number of relevant factors. *Journal of Econometrics*, *229*(1), 80–102. https://doi.org/10.1016/j.jeconom.2021.04.006

Ghazali, P. L., Fauzi, S. N. M., Rohim, R. A. A., Razak, R. A., Arifin, J., Zain, E. N. M., & Foziah, N. H. M. (2023). Construction of Mathematical Start-Up Business Index Formulation for Swiftlet Ranching Industry in Malaysia. *Contemporary Mathematics (Singapore)*, *4*(4), 1125–1134. https://doi.org/10.37256/cm.4420232748

Gushendri, Aimon, H., & Sentosa, S. U. (2023). Analysis of Catch and Fishermen Family Welfare in West Sumatra Province: Simultaneous Equation Approach. *International Journal of Sustainable Development and Planning*, *18*(5), 1329–1338. https://doi.org/10.18280/ijsdp.180503

Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., Webster, S., Cameron-Blake, E., Hallas, L., Majumdar, S., & Tatlow, H. (2021). A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nature Human Behaviour*, *5*(4), 529–538. https://doi.org/10.1038/s41562-021-01079-8

Han, X., Yue, B., & He, Z. (2023). Thriving in uncertainty: examining the relationship between perceived environmental uncertainty and corporate eco-innovation through the lens of dynamic capabilities. *Frontiers in Environmental Science*, *11*(June), 1–17. https://doi.org/10.3389/fenvs.2023.1196997

Haque, R. & Joshi, H. (2011). Marketing Communication: Thinking outside The Box And Moving Beyond Promotion Mix. *Asian Journal of Technology & Management Research (AJTMR)*, 1(1), 1-7. http://www.ajtmr.com/archives.aspx

Haque, R., Senathirajah, A.R.b.S., Khalil, M.I., Qazi, S.Z.; Ahmed, S. (2024). A Structural Path Analysis Bangladeshi SMEs'Sustainability through Social Media Marketing. *Sustainability*, 16(13), 5433. https://doi.org/10.3390/su16135433

Heilporn, G. and Lakhal, S. (2010). Environmental facilitators and barriers to student persistence in online courses: reliability and validity of new scales Géraldine. *The Journal of Continuing Higher Education*, *58*(1), 59–60. https://doi.org/10.1080/07377360903547675

Ismail, K., Ishak, R., & Kamaruddin, S. H. (2021). Development of Professional Learning Communities Model using Fuzzy Delphi Approach. *TEM Journal*, *10*(2), 872–878. https://doi.org/10.18421/TEM102-48

Izzah, S. N., Sudarmin, Wiyanto, & Wardani, S. (2024). Evaluation of students' environmental attitude instruments: exploratory and confirmatory factor analysis. *International Journal of Evaluation and Research in Education* , *13*(1), 347–354.

https://doi.org/10.11591/ijere.v13i1.25769
Jamaludin Malik, H. K. (2021). Jurnal Pengelolaan Perikanan Tropis Journal of Tropical Fisheries Management. *Journal of Tropical Fisheries Management*, *05*(2018).
Jing, L., Senathirajah, ARS., Haque, R., Devasia, S.N., Krishnasamy, H.N., Isa, AMM., & Ramasam, G. (2023). The Influence Of E-Service Quality Dimensions On Customer Satisfaction Aimed At Improving Economic Growth In China's Online Apparel E-market place. *International Journal of Operations and Quantitative Management*, 29(3). 83-103. https://doi.org/10.46970/2023.29.3.06
Jonathan Muterera. (2024). The Auditor Self-Efficacy Scale: Measuring Confidence in Technical Skills, Technological Adaptation, and Interpersonal Communication. *Finance & Accounting Research Journal*, *6*(3), 331–346. https://doi.org/10.51594/farj.v6i3.873
Jones, R., & Parry, S. (2011). Business support for new technology-based firms: A study of entrepreneurs in north Wales. *International Journal of Entrepreneurial Behaviour and Research*, *17*(6), 645–662. https://doi.org/10.1108/13552551111174710
Jubinville, I., Lawler, E., Tattrie, S., Shackell, N. L., Flemming, J. M., & Worm, B. (2021). Distributions of threatened skates and commercial fisheries inform conservation hotspots. *Marine Ecology Progress Series*, *679*, 1–18. https://doi.org/10.3354/meps13938
Kaur, K., Ya'akub, N.I., Keong, C.S., Singh, J., Sandhu, S.K., Senathirajah, A.R.S. & Haque, R. (2023). Examining Factors Influencing Fashion Apparel Purchases in Omni-Channel Retailing: A Post-Covid-19 Study. *Transnational, Marketing Journal,* 11(1), 44-58. https://doi.org/10.33182/tmj.v10i3.2182
Khalil, M.I., Haque, R., Senathirajah, A.R.S., Chawdhury, B. & Ahmed, S. (2022). Factors Affecting The Growth Of Smes In Bangladesh: A Structured Equation Modeling Approach. I*nternational Journal of e-Business and e-Government Studies,* 14(3), 578-593. https://doi.org/10.34109/ijebeg. 202214128
Kucheryavskiy, S., Zhilin, S., Rodionova, O., & Pomerantsev, A. (2020). Procrustes Cross-Validation - A Bridge between Cross-Validation and Independent Validation Sets. *Analytical Chemistry*, *92*(17), 11842–11850. https://doi.org/10.1021/acs.analchem.0c02175
Kurniawan, F. E., & Aini, Y. N. (2022). Mapping of Changes in the Utilization of Marine Resources in the Small-Scale Fisheries Subsector in Indonesia (2008-2017). *Jurnal Perikanan Universitas Gadjah Mada*, *24*(1), 21. https://doi.org/10.22146/jfs.68659
Lee, P.X., Senathirajah, ARS., Al-Ainati, S., Isa, A.M.M., Haque, R., Krishnasamy, H.N., Parameswaran, S., & Devasia, S.N. (2023). Factors Influencing Job Hopping Behaviour Amongst Finance Professionals: Towards Improving Employment Policy. *International Journal of Operations and Quantitative Management*, 29(2), 360-377. https://doi.org/10.46970/2023.29.2.17
Li, F., Deng, L., Li, L., Cheng, Z., & Yu, H. (2020). A two-stage model for monitoring the green supplier performance considering dual-role and undesirable factors. *Asia Pacific Journal of Marketing and Logistics*, *32*(1), 253–280. https://doi.org/10.1108/APJML-02-2019-0110
Li, Y., & Ji, J. (2022). Evaluation of Marine Fisheries Vulnerability in China and Its Spatial Effects: Evidence from Coastal Regions. *Agriculture (Switzerland)*, *12*(6), 1–16. https://doi.org/10.3390/agriculture12060809
Lichtveld, M. Y., Covert, H. H., Sherman, M., Shankar, A., Wickliffe, J. K., & Alcala, C. S. (2019). Advancing environmental health literacy: Validated scales of general environmental health and environmental media-specific knowledge, attitudes and behaviors. *International Journal of Environmental Research and Public Health*, *16*(21), 1–13. https://doi.org/10.3390/ijerph16214157
Malarvizhi, C.A.N., Manzoor, S.R. & Haque, R. (2024). Revisiting the Extended IoT Use Behavior Model Among Senior NCD Patients for Smart Healthcare in Malaysia. *International Journal of Service Science, Management, Engineering, and Technology*, 15(1), 1-25. https://doi.org/10.4018/IJSSMET.34991
Mkuna, E., & Baiyegunhi, L. J. S. (2019). Analysis of the technical efficiency of Nile perch (Lates niloticus) fishers in the Tanzanian portion of Lake Victoria: A stochastic frontier analysis. *Lakes and Reservoirs: Science, Policy and Management for Sustainable Use*, *24*(3), 228–238. https://doi.org/10.1111/lre.12274
Mugo, R., Saitoh, S. I., Nihira, A., & Kuroyama, T. (2010). Habitat characteristics of skipjack tuna (Katsuwonus pelamis) in the western North Pacific: a remote sensing perspective. *Fisheries*

Oceanography, *19*(5), 382–396. https://doi.org/10.1111/j.1365-2419.2010.00552.x

Murray, C. W., Erlanson, D. A., Hopkins, A. L., Keseru, G. M., Leeson, P. D., Rees, D. C., Reynolds, C. H., & Richmond, N. J. (2014). Validity of Ligand E ffi ciency Metrics. *ACS Medicinal Chemistry Letters*.

Narayanan, S., Haque, R., bin S Senathirajah, A. R., OmarDin, F. M., Isa, M. b. M., Ramasamy, G., Krishnasamy, H. N. (2024). Workplace Romance and Organisational Performance: A Case Study of Malaysian Oeganizations. *International Journal of Instructional Cases*, 8(1), 121-134. https://ijicases.com/menuscript/index.php/ijicases/article/view/111/79

Narayanan, S., Rahim, H.A., Haque, R., Senathirajah, A.R.S., & Din, F.M.B.O.. (2023). Empirical Study On Effects Of Corporate Social Responsibility On Organizational Performance In Manufacturing Sectors, Nigeria: Flour Mills Nigeria Plc. *Res Militaris, European Journal of Military Studies*, 13(2), 1246-1265. https://resmilitaris.net/menuscript/index.php/resmilitaris/article/view/2407/1989

Nenadović, M., Basurto, X., & Weaver, A. H. (2016). Contribution of Subsidies and Participatory Governance to Fishers' Adaptive Capacity. *Journal of Environment and Development*, *25*(4), 426–454. https://doi.org/10.1177/1070496516670448

Pagliacci, F. (2017). Measuring EU Urban-Rural Continuum Through Fuzzy Logic. *Tijdschrift Voor Economische En Sociale Geografie*, *108*(2), 157–174. https://doi.org/10.1111/tesg.12201

Paterson, B., Jarre, A., Moloney, C. L., Fairweather, T. P., Van Der Lingen, C. D., Shannon, L. J., & Field, J. G. (2007). A fuzzy-logic tool for multi-criteria decision making in fisheries: The case of the South African pelagic fishery. *Marine and Freshwater Research*, *58*(11), 1056–1068. https://doi.org/10.1071/MF07060

Peltier, J. W., Zhao, Y., & Schibrowsky, J. A. (2012). Technology adoption by small businesses: An exploratory study of the interrelationships of owner and environmental factors. *International Small Business Journal*, *30*(4), 406–431. https://doi.org/10.1177/0266242610365512

Pinello, D., Liontakis, A., Sintori, A., Tzouramani, I., & Polymeros, K. (2016). Assessing the efficiency of small-scale and bottom trawler vessels in Greece. *Sustainability (Switzerland)*, *8*(7), 1–11. https://doi.org/10.3390/su8070681

Price, A. R. (2001). The marine food chain in relation to biodiversity. *TheScientificWorldJournal*, *1*, 579–587. https://doi.org/10.1100/tsw.2001.85

Rana, M., Ahmed, S., Haque, R., Senathirajah, A.R.S., Khalil, M.A., & Chawdhury, B. (2023). Job Satisfaction: A Study On Bangladesh Civil Service Field Level Administration. *Res Militaris, European Journal of Military Studies*, 13(2), 1292-1321. https://resmilitaris.net/menuscript/index.php/resmilitaris/article/view/2410/1992

Rice, E. D., Bennett, A. E., Muhonda, P., Katengeza, S. P., Kawaye, P., Liverpool-Tasie, L. S. O., Infante, D. M., & Tschirely, D. L. (2023). Connecting gender norms and economic performance reveals gendered inequities in Malawian small-scale fish trade. *Maritime Studies*, *22*(4), 1–15. https://doi.org/10.1007/s40152-023-00337-x

Robinson, V. B. (2007). Issues and challenges of incorporating fuzzy sets in ecological modeling. *NATO Security through Science Series C: Environmental Security*, 33–51. https://doi.org/10.1007/978-1-4020-6438-8_3

Saghaie, L., Shahlaei, M., Fassihi, A., Madadkar-Sobhani, A., Gholivand, M. B., & Pourhossein, A. (2011). QSAR Analysis for Some Diaryl-substituted Pyrazoles as CCR2 Inhibitors by GA-Stepwise MLR. *Chemical Biology and Drug Design*, *77*(1), 75–85. https://doi.org/10.1111/j.1747-0285.2010.01053.x

Schmacker, E. R., & McKay, N. L. (2008). Factors affecting productive efficiency in primary care clinics. *Health Services Management Research*, *21*(1), 60–70. https://doi.org/10.1258/hsmr.2007.007018

Senathirajah, ARS., Haque, R., Abbas, S., Isa, AMM., Udang, L.N., Ramasamy, G., & Krishnasamy, H.N. (2023). A Quantitative Analysisof Global Scientific Literature On Tourism And Digital Economy- Moving Towards Sustainable Tourism. *International Journal of Operations and Quantitative Management*, 29(3), 129-142. https://doi.org/10.46970/2023.29.3.08

Sesabo, J. K., & Tol, R. S. J. (2007). Technical efficiency of small-scale fishing households in Tanzanian coastal villages: An empirical analysis. *African Journal of Aquatic Science*, *32*(1), 51–61. https://doi.org/10.2989/AJAS.2007.32.1.8.145

Soomro, K. A., Kale, U., Curtis, R., Akcaoglu, M., & Bernstein, M. (2018). Development of an instrument to measure Faculty's information and communication technology access (FICTA). *Education*

and Information Technologies, *23*(1), 253–269. https://doi.org/10.1007/s10639-017-9599-9

Sowman, M. (2011). New perspectives in small-scale fisheries management: Challenges and prospects for implementation in South Africa. *African Journal of Marine Science*, *33*(2), 297–311. https://doi.org/10.2989/1814232X.2011.602875

Sowman, M., Sunde, J., Pereira, T., Snow, B., Mbatha, P., & James, A. (2021). Unmasking governance failures: The impact of COVID-19 on small-scale fishing communities in South Africa. *Marine Policy*, *133*. https://doi.org/10.1016/j.marpol.2021.104713

Sulanke, E., & Rybicki, S. (2021). Community Development Quotas and Support of Small-Scale Fisheries as Two Key Concepts for Blue Growth in Fisheries. *Frontiers in Marine Science*, *8*(November), 1–20. https://doi.org/10.3389/fmars.2021.752764

Sulu, R. J., Eriksson, H., Schwarz, A. M., Andrew, N. L., Orirana, G., Sukulu, M., Oeta, J., Harohau, D., Sibiti, S., Toritela, A., & Beare, D. (2015). Livelihoods and fisheries governance in a contemporary Pacific Island setting. *PLoS ONE*, *10*(11), 1–23. https://doi.org/10.1371/journal.pone.0143516

Sun, Y., Wan, L., Liang, X., & Xu, Y. (2007). Study on the control of GDROV based on fuzzy direct adaptive theory. *Proceedings of the 2007 IEEE International Conference on Mechatronics and Automation, ICMA 2007*, 3327–3332. https://doi.org/10.1109/ICMA.2007.4304096

Sunanta, O. (2018). Generalized point estimators for fuzzy multivariate data. *Austrian Journal of Statistics*, *47*(1), 33–44. https://doi.org/10.17713/ajs.v47i1.391

Sylaios, G. K., Koutroumanidis, T., & Tsikliras, A. C. (2010). Ranking and classification of fishing areas using fuzzy models and techniques. *Fisheries Management and Ecology*, *17*(3), 240–253. https://doi.org/10.1111/j.1365-2400.2009.00714.x

Taleb, O. K., Siti-Azrin, A. H., Sarimah, A., Abusafia, A. H., Baharuddin, K. A., & Wan-Nor-Asyikeen, W. A. (2023). Psychometric properties of the environmental factors' questionnaire for undergraduate medical students taking online learning during COVID-19 pandemic: a cross-sectional study. *BMC Medical Education*, *23*(1), 1–8. https://doi.org/10.1186/s12909-023-04314-0

Tamir, D. E., Rishe, N. D., & Kandel, A. (2015). Complex fuzzy sets and complex fuzzy logic an overview of theory and applications. *Studies in Fuzziness and Soft Computing*, *326*, 661–681. https://doi.org/10.1007/978-3-319-19683-1_31

Teh, L. C. L. (2020). Are fishers poor? Getting to the bottom of marine fisheries income statistics. *Fish and Fisheries*, *21*(3), 471–482. https://doi.org/10.1111/faf.12441

Teh, L. C. L., & Pauly, D. (2018). Who brings in the fish? The relative contribution of small-scale and industrial fisheries to food security in Southeast Asia. *Frontiers in Marine Science*, *4*(FEB), 1–9. https://doi.org/10.3389/fmars.2018.00044

Teh, L. S. L., Teh, L. C. L., & Sumaila, U. R. (2011a). Low discounting behavior among small-scale fishers in Fiji and Sabah, Malaysia. *Sustainability*, *3*(6), 897–913. https://doi.org/10.3390/su3060897

Teh, L. S. L., Teh, L. C. L., & Sumaila, U. R. (2011b). Quantifying the overlooked socio-economic contribution of small-scale fisheries in Sabah, Malaysia. *Fisheries Research*, *110*(3), 450–458. https://doi.org/10.1016/j.fishres.2011.06.001

Testa, F., Gusmerottia, N. M., Corsini, F., Passetti, E., & Iraldo, F. (2016). Factors Affecting Environmental Management by Small and Micro Firms: The Importance of Entrepreneurs' Attitudes and Environmental Investment. *Corporate Social Responsibility and Environmental Management*, *23*(6), 373–385. https://doi.org/10.1002/csr.1382

Tian, T. (2004). Robustness of mathematical models for biological systems. *ANZIAM Journal*, *45*, 565. https://doi.org/10.21914/anziamj.v45i0.908

Tzer, L.S., Safiyuddin, F.S., Haque, R., Noordin, N.M., Manickam, L., Hakimi, N. (2024). Exploring the Impact of Marketing Mix Products Transformation Strategies in Glove Manufacturing Industries: A Case Study. *Pakistan Journal of Life and Social Sciences*, 22(2), 1477-1792. https://doi.org/10.57239/PJLSS-2024-22.2.00104

Ul Haq, E., Ul Hassan, Q. M., Ahmad, J., & Ehsan, K. (2022). Fuzzy solution of system of fuzzy fractional problems using a reliable method. *Alexandria Engineering Journal*, *61*(4), 3051–3058. https://doi.org/10.1016/j.aej.2021.08.034

Wai, L.C., Isa, A.M.M., Bhandari, P., Senathirajah, ARBS., Haque, R., Devasia, S.N., Ramasamy, G.,

Krishnasamy, H.N., Al-Hunaiyyan, A. (2024). Factors Influencing Job Satisfaction to Ensure Sustainable Growth amongst Family-Owned Organizations in Malaysia. *Kurdish Studies*, 12(1), 3144-3173. https://doi.org/10.58262/ks.v12i1.227

Wee, Y. S., & Quazi, H. A. (2005). Development and validation of critical factors of environmental management. *Industrial Management and Data Systems*, *105*(1), 96–114. https://doi.org/10.1108/02635570510575216

Wicaksono, B. R. (2019). the Fisheries Subsidies in Indonesia and China. *Jurnal Ekonomi & Studi Pembangunan*, *20*(2). https://doi.org/10.18196/jesp.20.2.5023

Wulfing, S., Kadba, A., Baker-Médard, M., & White, E. R. (2024). Assessing the need for temporary fishing closures to support sustainability for a small-scale octopus fishery. *Fisheries Research*, *276*, 1–17. https://doi.org/10.1016/j.fishres.2024.107045

Yatsu, A., Watanabe, T., Ishida, M., Sugisaki, H., & Jacobson, L. D. (2005). Environmental effects on recruitment and productivity of Japanese sardine Sardinops melanostictus and chub mackerel Scomber japonicus with recommendations for management. *Fisheries Oceanography*, *14*(4), 263–278. https://doi.org/10.1111/j.1365-2419.2005.00335.x

Yavari Nejad, F., & Varathan, K. D. (2021). Identification of significant climatic risk factors and machine learning models in dengue outbreak prediction. *BMC Medical Informatics and Decision Making*, *21*(1), 1–12. https://doi.org/10.1186/s12911-021-01493-y

Yusoff, A. F. M., Hashim, A., Muhamad, N., & Hamat, W. N. W. (2021). Application of Fuzzy Delphi Technique to Identify the Elements for Designing and Developing the e-PBM PI-Poli Module. *Asian Journal of University Education*, *17*(1), 292–304. https://doi.org/10.24191/ajue.v17i1.12625

Zadeh, L., Schmitt, P. H., & Mundici, D. (1997). *Multiple-valued Logic*.

Zamzami, L., & Effendi, N. (2023). Community Development Quotas and Support of Small-Scale Fisheries as Two Key Concepts for Blue Growth in Fisheries. *Frontiers in Marine Science*, *7*(3), 1–20. https://doi.org/10.1016/j.fishres.2011.06.001

Zeller, D., Booth, S., & Pauly, D. (2006). Fisheries contributions to the gross domestic product: Underestimating small-scale fisheries in the pacific. *Marine Resource Economics*, *21*(4), 355–374. https://doi.org/10.1086/mre.21.4.42629521

Ziaei Ghahnavieh, M., Habibi Manesh, H., & Sheikhmoradi, S. (2024). Comparative comparison of fuzzy logic and classical logic. *Int. J. Nonlinear Anal. Appl*, *15*(January), 2008–6822. http://dx.doi.org/10.22075/ijnaa.2024.32978.4905