

# FuzzyDelphiJmv: Jamovi Module for Fuzzy Delphi Module

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## Abstract

The Fuzzy Delphi Method (FDM) is a structured framework that plays a significant role in decision-making and forecasting processes. It provides a methodical approach to utilising the opinions of experts. By incorporating a broader range of fuzzy numbers, fuzzy decision-making enhances analytical precision and adaptability compared to traditional Delphi approaches. This represents a notable advantage. To accommodate the inherent complexities present in decision-making processes, this innovative approach enables the conduct of studies that are both nuanced and flexible. The integration of FuzzyDelphiJmv offers researchers a user-friendly interface that streamlines the application of FDM. This is achieved by utilising the capabilities of Jamovi, an open-source statistical software developed in R programming. Researchers lacking coding experience may struggle to accurately compute the FDM calculation formula and interpret the results. To facilitate insightful analysis without requiring extensive programming skills, the output of the module has been intentionally designed to be straightforward and easily interpretable. FuzzyDelphiJmv is a Jamovi model developed using the Extreme Programming agile software development methodology, which emphasizes iterative refinement and user-centric design. This ensures that the model is both effective and accessible for assisting decision-making processes across various disciplines. The integration of FDM principles with accessible open-source statistical software represents a significant advancement in equipping researchers with the tools necessary to navigate complex decision-making landscapes with confidence and precision.

**Keywords:** Jamovi Module, Fuzzy Delphi Method, Open-Source Software, R Programming, Extreme Programming

## 1. Introduction

The Fuzzy Delphi Method (FDM) is a useful tool for decision-making and forecasting that provides a structured way to collect and evaluate expert opinions. FDM enables the inclusion of a broader spectrum of fuzzy numbers, improving the accuracy and adaptability of the analysis compared to the conventional Delphi method. The integration of FuzzyDelphiJmv with Jamovi, an open-source statistical software, offers a user-friendly interface for researchers to do FDM studies, especially those with no or low programming skills. This work introduces FuzzyDelphiJmv and showcases its usability and usefulness in assisting researchers in decision-making.

### 1.1 Fuzzy Delphi Method

The Fuzzy Delphi Method (FDM) is a modified and enhanced version of the classical Delphi technique [1]. It addresses the limitation of the traditional Delphi method (DM) by improving convergence, preventing loss of important information and reducing the investigation process. The Fuzzy Delphi method collects expert opinions as fuzzy numbers, allowing for a wider range of fuzzy numbers to be considered, not just triangular or trapezoidal fuzzy numbers [2].

### 1.2 Jamovi

Jamovi is an open source statistical software that is easy to use and is designed for researchers or students [3]. Jamovi is developed by a team who branches off from JASP [4]. The University of Amsterdam developed JASP, a user-friendly software interface based on R, for statistical analysis and education [5]. Jamovi allows to conduct data analysis. It can be installed on different desktop based operating systems [3]. The software offers essential features such data input and manipulation, rule-based data filtering, variable transformation, and variable computation.

Jamovi is community-driven, enabling users to incorporate new features by utilising modules [6]. Module development required understanding of R programming is important for advanced aspects of Jamovi [6, 7].

### 1.3 Purpose of the research paper

FuzzyDelphiJmv is designed to be user-friendly for researchers with few or no programming skills, enabling them to utilise the R package efficiently. The module's output is deliberately designed to be straightforward and analysable. Researchers are expected to utilise this module and consider all outcomes comprehensively for their interpretation.

## 2. Literature Review

### 2.1 Literature Review on Fuzzy Delphi Method

FDM was first proposed in the mid-1980s by Murray, Pipino, and Gigch. It involves the application of fuzzy set theory to the standard Delphi approach, with the goal of resolving the inherent ambiguity in semantic variables [8]. In the early 1990s, Ishikawa, et al. [1] made important contributions to the evolution of FDM by utilising approaches such as the maximum-minimum method, cumulative frequency distribution, and fuzzy scoring to efficiently combine expert views into fuzzy numbers. In 1996, Hsu and Chen introduced a fuzzy aggregate equation, which significantly improved the entire FDM process, marking a crucial milestone in its progress [9]. Since the 2000s, the FDM has gained greater recognition and acceptance in several academic disciplines, including as education, healthcare, management, and technology. Researchers have adopted the FDM because of its effectiveness in managing ambiguity and promoting agreement among specialists [10-13]. This strategy has been crucial in dealing with intricate decision-making situations, leading to a more refined and strong approach to aggregating expert opinions. The trajectory of the FDM demonstrates its ongoing improvement and adjustment, rendering it a valuable instrument in the domain of scholarly investigation and problem-solving.

### 2.2 Advantages

FDM has notable benefits that greatly enhance its efficacy in decision-making procedures. One significant advantage is its ability to handle the inherent ambiguity and vagueness included in expert judgements [1, 13]. The FDM allows experts to communicate their opinions using language phrases like "very important" or "somewhat likely," which allows for a more natural articulation of subjective

judgements without the limitations of precise numerical values. In addition, the FDM is notable for its efficacy, sometimes necessitating less iterations of surveys in comparison to conventional Delphi methodologies [1, 2]. This efficient technique not only saves time but also decreases expenses linked to lengthy consultation procedures [13]. The method's capacity to enhance precision is an additional notable benefit, since it encompasses a wider range of expert perspectives, reducing the influence of extreme viewpoints and yielding more dependable outcomes [13]. Moreover, the FDM facilitates improved group decision-making by encouraging cooperation and openness throughout the process [13-15]. Experts may analyse how their viewpoints contribute to the broader agreement, promoting a more knowledgeable and mutually endorsed ultimate determination. In summary, these benefits establish the FDM as a powerful and practical tool for navigating intricate decision-making situations.

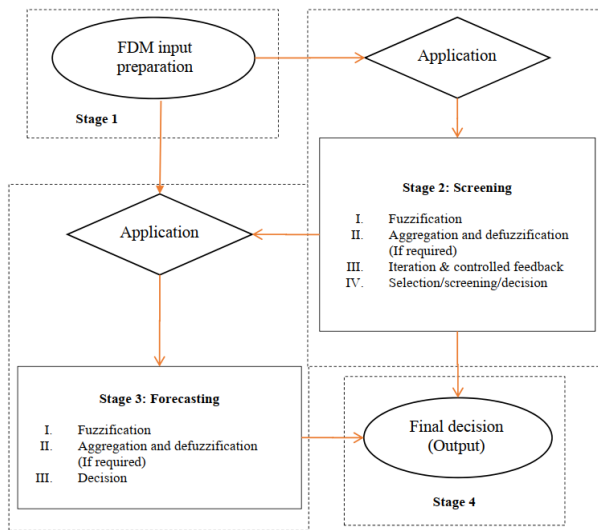
### 2.3 Steps involved in the Fuzzy Delphi Method

In complicated research circumstances, the FDM accommodates and methodically addresses uncertainties and imprecisions, improving study validity. FDM's fuzzy logic lets researchers collect and model expert opinions more loosely and accurately, representing numerous perspectives. This methodological approach allows language phrases and fuzzy sets to be used to communicate subjective judgments and manage unclear information. Kahraman and Ertay [16] demonstrate how FDM may overcome standard approaches' shortcomings when dealing with imprecise data in decision-making. FDM improves analysis by accepting study context ambiguity, boosting research validity in several fields.

Additionally, Liu and Tsai [17] work highlights the Fuzzy Delphi Method's influence on research validity. Their empirical study shows that FDM reduces biases and improves decision-making across research contexts. In circumstances where traditional approaches fail, FDM's fuzzy sets may manage conflicting and overlapping expert views to analyse varied viewpoints more thoroughly. In uncertain industries like business, healthcare, and technology, flexibility to complex and dynamic settings is vital. These findings demonstrate that fuzzy logic in the Delphi process acknowledges data uncertainties and gives researchers with an organised and rigorous strategy to negotiate such complexity, improving study validity.

As described in Bellman and Zadeh [18] original work, FDM's flexibility to changing settings and ability to absorb new knowledge boost its validity. Their foundational study illuminates fuzzy logic's

theoretical foundations and highlights its usefulness in dynamic research areas. FDM follows excellent research technique by quantifying subjective information and decreasing biases, boosting trust in conclusions.



**Fig. 1.** Framework of Fuzzy Delphi Method adapted from Saffie, et al. [13]

The fuzzy inference system is enhanced by implementing seven linguistic variables rather than five linguistic variables, as this can improve its performance and accuracy [19, 20]. In addition, seven linguistic words provide researchers with a finer and more exact control action that can more successfully produce the desired output [19, 20]. The formula for the detailed step-by-step procedure of stage 2 screening is provided in the Table 1.

**Table 1**  
Step-by-step procedure of stage 2 screening

Step no	Step description	Formulation																																																																																
1	The determination of triangular fuzzy numbers	<table border="1"> <thead> <tr> <th colspan="2">7 Linguistic variables</th> <th colspan="3">Fuzzy scales</th> </tr> <tr> <th></th> <th></th> <th><math>m_1</math></th> <th><math>m_2</math></th> <th><math>m_3</math></th> </tr> </thead> <tbody> <tr> <td>Strongly disagree</td> <td></td> <td>0.0</td> <td>0.0</td> <td>0.1</td> </tr> <tr> <td>Disagree</td> <td></td> <td>0.0</td> <td>0.1</td> <td>0.3</td> </tr> <tr> <td>Somewhat disagree</td> <td></td> <td>0.1</td> <td>0.3</td> <td>0.5</td> </tr> <tr> <td>Neither agree nor disagree</td> <td></td> <td>0.3</td> <td>0.5</td> <td>0.7</td> </tr> <tr> <td>Somewhat agree</td> <td></td> <td>0.5</td> <td>0.7</td> <td>0.9</td> </tr> <tr> <td>Agree</td> <td></td> <td>0.7</td> <td>0.9</td> <td>1.0</td> </tr> <tr> <td>Strongly agree</td> <td></td> <td>0.9</td> <td>1.0</td> <td>1.0</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th colspan="2">5 Linguistic variables</th> <th colspan="3">Fuzzy scales</th> </tr> <tr> <th></th> <th></th> <th><math>m_1</math></th> <th><math>m_2</math></th> <th><math>m_3</math></th> </tr> </thead> <tbody> <tr> <td>Strongly disagree</td> <td></td> <td>0.0</td> <td>0.0</td> <td>0.2</td> </tr> <tr> <td>Disagree</td> <td></td> <td>0.0</td> <td>0.2</td> <td>0.4</td> </tr> <tr> <td>Neither agree nor disagree</td> <td></td> <td>0.2</td> <td>0.4</td> <td>0.6</td> </tr> <tr> <td>Agree</td> <td></td> <td>0.4</td> <td>0.6</td> <td>0.8</td> </tr> <tr> <td>Strongly agree</td> <td></td> <td>0.6</td> <td>0.8</td> <td>1.0</td> </tr> </tbody> </table> <p>All linguistic variables used on the questionnaire are changed to triangular fuzzy numbers [13]. These triangular fuzzy numbers represent the values <math>m_1</math>, <math>m_2</math>, and <math>m_3</math>. The value of <math>m_1</math> is the smallest conceivable value, <math>m_2</math> is the rational value, and <math>m_3</math> is the largest possible value [21].</p>	7 Linguistic variables		Fuzzy scales					$m_1$	$m_2$	$m_3$	Strongly disagree		0.0	0.0	0.1	Disagree		0.0	0.1	0.3	Somewhat disagree		0.1	0.3	0.5	Neither agree nor disagree		0.3	0.5	0.7	Somewhat agree		0.5	0.7	0.9	Agree		0.7	0.9	1.0	Strongly agree		0.9	1.0	1.0	5 Linguistic variables		Fuzzy scales					$m_1$	$m_2$	$m_3$	Strongly disagree		0.0	0.0	0.2	Disagree		0.0	0.2	0.4	Neither agree nor disagree		0.2	0.4	0.6	Agree		0.4	0.6	0.8	Strongly agree		0.6	0.8	1.0
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2	The determination of average responses	The following formula (1) will be used to get the average value of each expert's response : $m = \frac{\sum_i^n m_i}{n}$ (1)						
3	The determination of threshold value, d	Using the formula (2), the threshold value ("d") between two fuzzy numbers ( $m = m_1, m_2, m_3$ ) and ( $n = n_1, n_2, n_3$ ) is then determined: $d(m, n) = \sqrt[3]{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]}$ (2) This "d" value must be $\leq 0.2$ for all experts to agree, based on Azudin, et al. [21].						
4	The determination of group consensus	Using the formula (3), the total value of the items within each construct must exceed 75% for the group to attain consensus : $\frac{\% \text{ of expert consensus for construct}}{\text{Total of "d"} < 0.2 * 100} \geq 75\%$ (3) Total of experts						
5	The identification of defuzzification	To calculate defuzzification, either of the following equations are used: <table border="1"> <tbody> <tr> <td>i</td> <td><math>A_{max} = \frac{m_1 + m_2 + m_3}{3}</math></td> </tr> <tr> <td>ii</td> <td><math>A_{max} = \frac{m_1 + 2m_2 + m_3}{4}</math></td> </tr> <tr> <td>iii</td> <td><math>A_{max} = \frac{m_1 + 4m_2 + m_3}{6}</math></td> </tr> </tbody> </table> <p>To indicate expert consensus, the resulting score numbers (defuzzification) must be between 0 and 1[22], and the alpha-cut value must be greater than 0.5 [20, 22].</p>	i	$A_{max} = \frac{m_1 + m_2 + m_3}{3}$	ii	$A_{max} = \frac{m_1 + 2m_2 + m_3}{4}$	iii	$A_{max} = \frac{m_1 + 4m_2 + m_3}{6}$
i	$A_{max} = \frac{m_1 + m_2 + m_3}{3}$							
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iii	$A_{max} = \frac{m_1 + 4m_2 + m_3}{6}$							
6	The ranking process	The process of positioning is carried out by defining elements based on defuzzification values based on expert consensus that the element with the highest relevance is the most significant location for decision-making [21, 23].						

Source adopted and adapted from Jani, et al. [20] and Azudin, et al. [21]

### 3. Methodology

#### 3.1 Extreme Programming agile model

An agile development paradigm that is lightweight, flexible, and low-risk, Extreme Programming (XP) is designed to accommodate ambiguous or rapidly changing requirements [24]. The Extreme Programming methodology places a strong emphasis on code review and substantial refactoring, and it necessitates an onsite presence for systems that take use of daily unit testing [25]. It is not necessary to have a large team to use XP because it is designed for teams of a small to medium size[24].

### 3.2 Development process of the FuzzyDelphiJmv Module

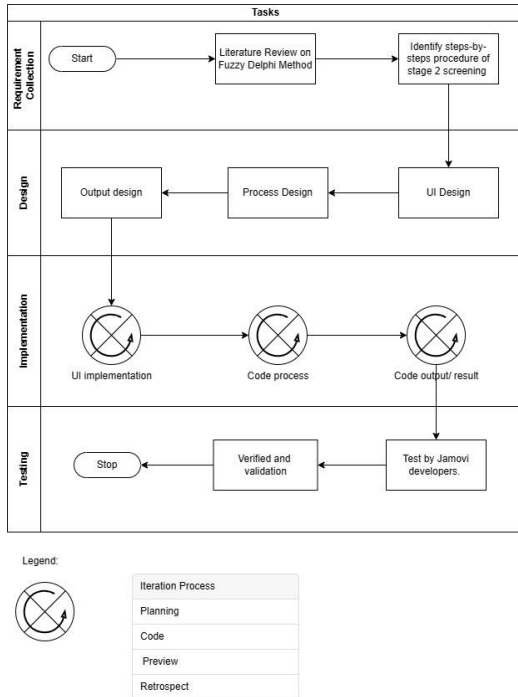


Fig. 2. Software development flow

#### 3.2.1 Requirement Collection

FDM is gaining attention in decision-making and forecasting for its capability to handle ambiguity and vagueness in expert judgements. An in-depth analysis of literature uncovers a diverse range of research investigating the concepts, modifications, and applications of FDM. Recent research has concentrated on thoroughly analysing and confirming the Stage 2 Screening process in the FDM framework. This is done through detailed calculations and rigorous testing, frequently using technologies such as Excel spreadsheets [26]. Commercial solutions like Fudelo 1.0 have been examined and evaluated for their effectiveness in aiding FDM-based analysis [27]. Nevertheless, the lack of open-source options has motivated academics to create an open-source FDM programme, in line with the principles of the open-source movement and with the goal of making FDM tools more accessible to all [28].

The choice to create an open-source iteration of FDM software is driven by the acknowledgment of the significance of accessibility and transparency in academic research and practical uses. This effort aims to enable researchers, practitioners, and decision-makers in many fields by connecting existing proprietary solutions with the increasing need for open-access tools. The open-source FDM programme is designed to provide a strong and user-friendly framework for doing FDM studies through careful planning, execution, and verification.

#### 3.2.2 Design

During the design phase of our research project, our team investigated the development of Jamovi modules to create a user interface that is user-friendly and effective for researchers. The focus of this project was creating a user interface that allows researchers to input data smoothly and provides freedom in choosing Likert scale alternatives. We used Jamovi's capabilities to create a user-friendly interface for easy data entry and customisation of Likert scale options to meet researchers' specific needs. The design strategy focused on improving user experience and usability to simplify data input and increase efficiency in performing FDM analyses.

We incorporated R programming techniques to develop the analytical framework of our open-source Jamovi module to enhance our analysis capabilities. We utilised the flexibility and capabilities of R to create an analysis module that includes the fundamental algorithms and methodologies necessary for FDM calculations. Our design allows researchers to do detailed FDM analyses effortlessly by utilising R's wide range of libraries and functions, enabling them to successfully explore and analyse complicated data sets. Our use of R programming principles demonstrates our dedication to providing a thorough and strong analytical system designed for the specific requirements of researchers, thus enhancing the availability and effectiveness of FDM in decision-making scenarios.

#### 3.2.3 Implementation

During the implementation phase of our research project, our team started developing the user interface, a crucial element designed to make data input and interaction easier for researchers. We spent about a week creating the interface design utilising Jamovi module development tools, focusing on making it intuitive and user-friendly. Subsequently, we moved on to the challenging task of FDM computation, which presented notable difficulties because of the intricacy of specific functions and the thorough unit testing needed for precision and dependability. For a period of one to one and a half months, we conducted thorough coding and testing to improve the FDM calculation process. Our goal was to ensure that our programme precisely reflected the subtleties of expert opinions and uncertainties present in decision-making scenarios.

Our attention then turned to creating advanced visualisations in the Jamovi environment, requiring collaboration and discussions with Jamovi developer Jonathan Love and other forum users. The joint project lasted around one month and included multiple

rounds of refining and redesigning the visualisation elements to achieve the high standards of clarity and interpretability required in academic research. After five cycles of modification and retesting, we successfully developed a strong and visually appealing presentation of FDM results in the Jamovi result area. This iterative method guaranteed the precision and dependability of our programme, showcasing our dedication to providing a top-notch analytical tool that enables researchers in their decision-making efforts.

### 3.2.4 Testing

We conducted unit testing iteratively to ensure the reliability and functioning of our software during the coding implementation phase of our research project. Using this iterative method helped us detect and resolve any errors or inconsistencies promptly, therefore improving the overall quality and reliability of our solution. Our study team intends to carry out user experience and evaluation verification and validation testing after publishing this work. We want to delay these tests to benefit from the knowledge and input obtained from academic discussions and peer review to enhance and confirm the usability and efficacy of our programme. This strategic approach highlights our dedication to providing a thorough and carefully verified solution for doing FDM analyses, therefore enhancing decision-making procedures.

## 4. Module integration

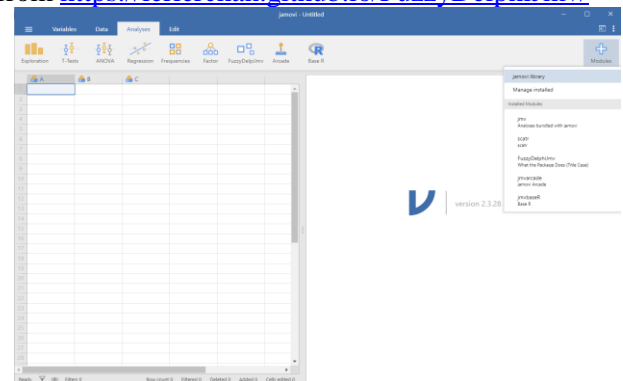
### 4.1 Module integrates with Jamovi

We developed FuzzyDelphiJmv to smoothly combine our FDM analysis module with Jamovi statistical tools. Using Jamovi's module development framework's flexibility and extensibility, we carefully designed an interface that easily interacts with Jamovi's user interface, allowing users to leverage FDM functionalities in Jamovi. FuzzyDelphiJmv enhances Jamovi's analytical capabilities by adding custom functions and visualisations for FDM analyses, allowing researchers and practitioners to use FDM for decision-making and forecasting.

FuzzyDelphiJmv's integration with Jamovi expands the ecosystem's analytical capabilities and makes Fuzzy Delphi Method analyses more accessible and usable. FuzzyDelphiJmv democratises FDM techniques by delivering a fluid and intuitive user experience, allowing researchers from diverse disciplines to employ FDM in their statistical workflows. FuzzyDelphiJmv shows our dedication to open-access and collaborative statistical analysis, which promotes innovation and improvement in decision-making methods.

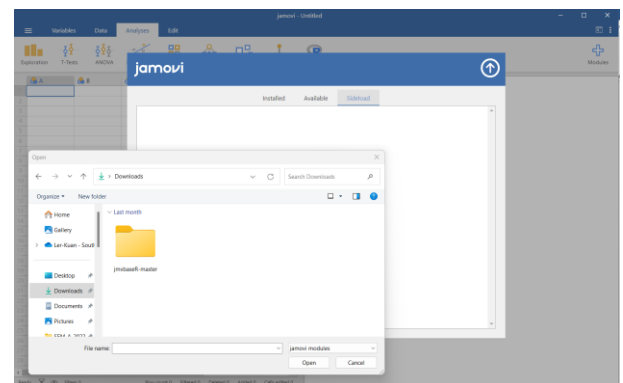
### 4.2 Installation guide

Firstly, install Jamovi app into your computer. Secondly, download the FuzzyDelphiMethod jmo from <https://lerlerchan.github.io/FuzzyDelphiJmv/>



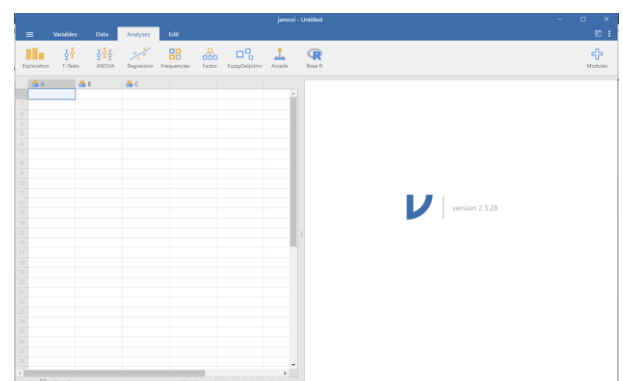
**Fig. 3.** Steps to add modules.

Once Jamovi app is installed and opened, click on Modules icon on the top right of the app. Choose Jamovi library.



**Fig. 4.** Load downloaded module to Jamovi

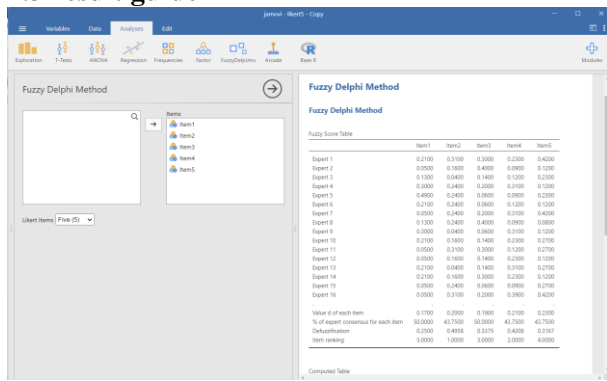
Select Sideload tab. Select the middle button and load the downloaded jmo file.



**Fig. 5.** Module added to Jamo

**FuzzyDelphiJmv will display on the gray menu area.**

### 4.3 result guide



**Fig. 6.** FDM calculation result will be displayed on the right-hand side (Result) area.

#### Fuzzy Delphi Method

Fuzzy Score Table

	Item1	Item2	Item3	Item4	Item5
Expert 1	0.2100	0.3100	0.3000	0.2300	0.4200
Expert 2	0.0500	0.1600	0.4000	0.0900	0.1200
Expert 3	0.1300	0.0400	0.1400	0.1200	0.2300
Expert 4	0.3000	0.2400	0.2000	0.3100	0.1200
Expert 5	0.4900	0.2400	0.0600	0.0900	0.2300
Expert 6	0.2100	0.2400	0.0600	0.1200	0.1200
Expert 7	0.0500	0.2400	0.2000	0.3100	0.4200
Expert 8	0.1300	0.2400	0.4000	0.0900	0.0800
Expert 9	0.3000	0.0400	0.0600	0.3100	0.1200
Expert 10	0.2100	0.1600	0.1400	0.2300	0.2700
Expert 11	0.0500	0.3100	0.3000	0.1200	0.2700
Expert 12	0.0500	0.1600	0.1400	0.2300	0.1200
Expert 13	0.2100	0.0400	0.1400	0.3100	0.2700
Expert 14	0.2100	0.1600	0.3000	0.2300	0.1200
Expert 15	0.0500	0.2400	0.0600	0.0900	0.2700
Expert 16	0.0500	0.3100	0.2000	0.3900	0.4200
Value d of each item	0.1700	0.2000	0.1900	0.2100	0.2300
% of expert consensus for each item	50.0000	43.7500	50.0000	43.7500	43.7500
Defuzzification	0.2500	0.4958	0.3375	0.4208	0.3167
Item ranking	5.0000	1.0000	3.0000	2.0000	4.0000

**Fig. 7.** Fuzzy Score table

The fuzzy scale table is a key improvement that helps researchers understand the fuzzy scores given to unique objects by each expert. This table is a thorough tool that offers significant insights into the evaluating process. The document contains crucial elements including the allocated value "d" for each item, the expert consensus percentage for each item, the defuzzification procedure, and the resultant item ranking. Thorough documentation provides researchers with a comprehensive insight into the topic matter, facilitating more accurate analysis and interpretation of research results. Scholars can improve the rigour and reliability of their studies by using a diverse approach to manage the complexity of fuzzy scoring systems.

Computed Table

	Item1	Item2	Item3	Item4	Item5
Value d of each item	0.170	0.200	0.190	0.210	0.230
% of expert consensus for each item	50.000	43.750	50.000	43.750	43.750
Defuzzification	0.250	0.496	0.337	0.421	0.317
Item ranking	5.000	1.000	3.000	2.000	4.000

Mean of item construct

	Average
Value d construct	0.20
% of expert consensus for construct	46.25

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[2] R Core Team (2021). *R: A Language and environment for statistical computing*. (Version 4.1) [Computer software]. Retrieved from <https://cran.r-project.org>. (R packages retrieved from MRAN snapshot 2022-01-01).

**Fig. 8.** Calculated table.

The calculated table is a significant tool for visualising data, displaying important metrics including the assigned value "d" for each item, the expert consensus percentage for each item, defuzzification results, and item ranks. Consolidating this extensive information into one presentation helps researchers acquire a clearer understanding and deeper insight into the evaluation process, making it easier to analyse and evaluate study findings. The mean of the item construct table provides a concise summary by displaying the average values of "d" constructs and the expert consensus percentages for each construct. This concise format allows researchers to see patterns, trends, and linkages in the data, enhancing the depth of their analytical work.

## 5. Conclusion

The incorporation of FuzzyDelphiJMV into the Jamovi statistical platform is a notable achievement in making the FDM more accessible and user-friendly for decision-making and forecasting. This collaboration improves the analytical features of Jamovi and makes FDM techniques more accessible by offering a smooth and user-friendly experience. We provide a strong and dependable solution for FDM analyses by going through iterative design, implementation, and testing phases. This approach helps us tackle the challenges posed by expert opinions and uncertainties in decision-making scenarios. Moreover, incorporating sophisticated visualisations and intuitive interfaces simplifies the FDM process, enabling researchers from various fields to efficiently employ FDM in their statistical analyses. FuzzyDelphiJMV promotes innovation and improvement in decision-making processes by

adopting open-source principles and collaborative development, leading to superior research outputs and informed decision-making procedures.

### 5.1 Recommendation for user evaluation

Our next step is to perform thorough user experience and evaluation studies for FuzzyDelphiJMv to confirm its effectiveness and gauge researcher satisfaction levels. We seek to collect useful information on the usability, functionality, and general user satisfaction of the programme by interacting with users from various academic and practical backgrounds. We will evaluate users' interactions with the platform, pinpoint areas for improvement, and collect feedback to enhance the user experience using structured surveys, interviews, and usability testing sessions. Our dedication to delivering a robust and user-friendly tool for FDM analysis is aligned with a user-centric strategy, ensuring that FuzzyDelphiJMv serves the increasing demands of researchers and decision-makers in many fields. Through thorough user review, we aim to validate the software to enhance confidence in its dependability and effectiveness, ultimately promoting its adoption and impact on decision-making processes.

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### Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Microsoft Copilot in order to improve the grammar and sentence structure. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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