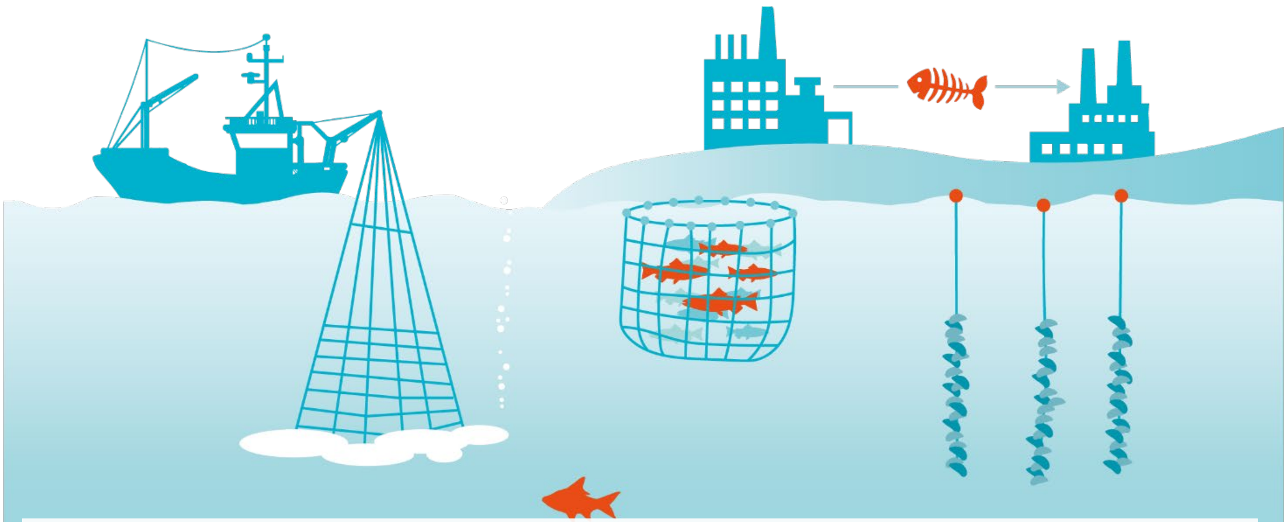
Optimal utilization of seafood side-streams through the design of new holistic process lines

D2.5 - Selection of decision tool in one supply chain and recommendation of support tools



Milestone type: Deliverable Report
WP number and title: WP 2.5 – Use of tools and methods to support decision-making.
Dissemination level: Public
Due date: Month 44 (Dec 2022)
Lead beneficiary for the task: DTU AQUA
Author: Søren Espersen Schrøder
Contributing Partners: DTU AQUA

Horizon 2020
European Union Funding
for Research & Innovation

Table of content

Executive summary 3

Introduction 4

Target 1: Selection of decision tool in one supply chain 4

Recommendation for support tools to the WAHP tool 7

Sum-up target 1 9

Target 2: Description of the debias support tool as a supplement to the WAHP tool 10

Conclusion 11

References 12

Executive summary

- Deliverable report 2.5 is a part of work package 2, task 2.5 and contains two targets.
  - Target 1: Selection of decision tool in one supply chain and recommendation of support tools is based on task 2.5 in connection to the output.
  - Target 2: Development of a new support tool for the industries that ensure a more unbiased approach in the organizations.

Related to Target 1.

- Based on an overview of the strengths and limitations of several Multi-Criteria-Decision-Making (MCDM) tools methodology, the Analytical Hierarchical Process (AHP) methodology can be recommended due to its strengths compared to the other MCDM methodologies to design the decision tool.
  - While the other MCDM methodologies could have been applied to the supply chain case (Proteins and savory compounds from mussel cooking water case" with project company Pescados Marcelino), their limitations, particularly the difficulty of use by a non-trained user, is a major factor in the recommendation of utilizing the AHP methodology.
  - WAHP is a term made by the designers of the decision support tool in task 2.4 and refers to a specialized AHP tool developed for WaSeaBi (WAHP).

- Recommendations for support tools to the WAHP tool has been made in this report to address the limitations of the WAHP tool being designed in task 2.4. These are:
  - Implementation of a pair-wise comparison approach to aid the tool user in creating decision weights for the WAHP tool.
  - Implementation of market analysis, risk analysis, or a price analysis to create input for the economic decision factors and to ensure that the economic results of the WAHP tool reflects the real market context as close as possible.
  - Implementation of a single score system to reduce information overload for the tool user when being presented the final AHP scores.
  - Implementation of support tools that can account for human subjectivity when assigning weights and input values for the WAHP tool.

Related to Target 2.

- The methodology of the developed support tool has been refined and turned into an article manuscript titled "*Making the objectively best choice for side-stream resources - Verification of debiasing method based on cognitive maps and attribute substitution."* The manuscript is currently in peer-review and feedback has been positive on the developed methodology for the new support tool developed in task 2.5. The manuscript can be provided on request.

- An overview of the features of the new decision support tool to account for a user's subjectivity and ensure a more unbiased approach is outlined in table 4 of this report.

- Both Target 1 and 2 for Deliverable 2.5 has been meet.

Introduction

This deliverable report, conducted in work package 2 under task 2.5, will focus on addressing the two targets detailed in the AMENDMENT Reference No AMD-837726-9 for the WaSeaBi project (Grant Agreement number: 837726) for deliverable D2.5:

> *Target 1: Selection of decision tool in one supply chain and recommendation of support tools is based on task 2.5 in connection to the output.*
>
> *Target* 2: *Development of a new support tool for the industries that ensure a more unbiased approach in the organizations.*

Task 2.5 is also a part of PhD study conducted at DTU AQUA named "*Decision Tools and Management in the Fish Sector – Examining the psychological components of the Analytical Hierarchy Processes methodology and its effect on decision making.*"

Target 1: Selection of decision tool in one supply chain

In task 2.4 it has been decided to create an Analytical Hierarchical Process (AHP) tool to support the project companies in their decisions making on side-stream exploitation. Given that the AHP tool being created will be specialized for use in the WaSeaBi project context it is also being referred to as a WAHP tool.

The supply chain chosen to be optimized using the WAHP tool by task 2.4 is the "*Proteins and savory compounds from mussel cooking water case*" with project company Pescados Marcelino. This case is detailed in task 3.1 under work package 3 and the deliverable report therein.

In brief a AHP tool is a Multi-Criteria-Decision-Making (MCDM) tool that is focused on provided a decision maker with an objective view of which alternative should be chosen. This objective view is generally visualized via an AHP Matrix (A matrix that includes all the weighted scores of the evaluated criteria related to a decision.) and its AHP scores (Saaty, 1980). The AHP score refers to the final evaluation score of each evaluated alternative that is being evaluated in a given scenario based on the pair-wise comparison of criteria in the AHP matrix. Often represented as a numerical representation of how useful or beneficial something is to a decision based on the evaluations of importance made in the AHP matrix (Saaty, 1980).

In brief, an AHP matrix is a matrix that includes all the weighted scores of the evaluated criteria related to a decision in a given scenario (e.g. scenario 1 could what mobile phone should I choose, scenario 2 could be which machine should we use to increase utilization of side-stream resources etc.). Under each scenario, a row of different alternatives can be chosen (e.g. the brand of mobile phone – see also below).

In AHP matrices, each criterion has its own row and column. The size of the matrix depends on the number of criteria e.g., three criteria give a 3x3 matrix, 9 criteria a 9x9 matrix and so forth. The resulting square matrix then allows pairwise comparison of all possible combinations of criteria by the decision maker to determine the most important decision factor. E.g., in an AHP matrix the decision maker may evaluate that the factor location compared to the factor cost is 7. This means that the factor location is seven times more important than the factor cost, while cost only is 1/7 as important as location for the decision. From the AHP matrix and the pair-wise comparisons, criteria weights are calculated for use in determining the AHP scores (Saaty, 1980). An AHP score is the final score of each alternative (e.g. the brand of mobile phone, processing machine, etc.) that is being evaluated based on the pair-wise comparison criteria in the AHP matrix and indicates the utility of a decision in the given scenario (Saaty, 1980).

For more detailed information on the WAHP tool created in task 2.4 please see deliverable report 2.4 and milestone report 3. In the MCDM tool field several other tool alternatives exist to the AHP methodology. These are shown in table 1 below together with their main strengths and limitations

MCDM technique	Strengths	Limitations
Analytic Hierarchy Process (AHP) (Saaty, 1980)	• Wide decision application opportunities for resource allocation. • An effortlessly decision support system for untrained users. • Disentangles a troublesome issue by separating it into littler steps. • Does not require authentic information sets. • Offers a simple route to handle complex decisions. • Handles supplement add-ons well.	• Human cognition and emotions are obscure. • Can't unravel non straight models. • Can't consider uncertainty and dangers • Choice making based on prior user experience. • Results are prone to subjectivity. • Issues with visualizing results.

Simple Additive Weighting (SAW)(MacCrimmon & Rand, 1968)	• Precise assessment results based on predetermined criteria and preference weights. • Relatively simple and effortless to operate.	• More suitable for credit cases (limited application range) • Requires predetermined criteria and preference weights to function. • Human cognition and emotions are not accounted for.
Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)(Hwang & Yoon, 1981)	• Ease of application • Provides a scalar value that accounts for both the best and worst alternatives simultaneously. • Relative simple computation process. • Ease of visualization of results in a polyhedron	• Results are prone to high subjectivity • Lacks weight elicitation • Lacks consistency checking for judgments • Human cognition and emotions are not accounted for.
Analytic Network Process (ANP) (Zeleny and Cochrane, 1982)	• Simplify complex problems • Quantitative description of subjective judgment • Include both intangible and intangible factors • Prioritize indicators • Allow dependence and feedback in hierarchy	• Heavily rely on experts' judgment and experiences • Large number of factors lead to unwieldy mode. • Human cognition and emotions are not accounted for.
Multi-Objective Optimization by Ratio Analysis (MOORA)(Brauers & Zavadskas, 2006)	• Can handle inaccurate and ambiguous evaluation data • Relatively simple and easy tool to use • High accuracy	• Struggles with more complex decision scenarios – Too many different and complex variables decrease the accuracy and ease of use.
ELECTRE (Roy, 1996)	• Wide decision application opportunities • Handles sorting relatively easy • Accounts for uncertainty and imprecision in the analysis. • Enables easy robustness analysis	• Relatively difficult tool to use (non-intuitive tool) • Results can be hard to explain and visualize • Its ranking approach makes it difficult to identify the strengths and weaknesses of attributes used.

Table 1: Overview of ten MCDM techniques with their strengths and limitations outlined. Sources are listed in correlation with the rows in the table (Karthikeyan et al. 2019; Putra & Punggara, 2018; Kochkina et al. 2017; Shih et al., 2007; Gu et al., 2018; Saravanan et al., 2022; Bezdrob et al., 2011)

Based on the overview. Due to its strengths compared to the other studied MCDM tools, the AHP methodology can be recommended to utilize in the supply chain case of mussel cooking water. This is primarily due to the methodologies strengths in being able to deconstruct relatively complex decision scenarios into manageable step in a process that is intuitive for non-trained user to engage with. It is therefore expected that the utilization of a AHP methodology to design the WAHP tool will be able to provide useful recommendations for which alternative Pescados Marcelino could choose to allocate their resources to in relation to their mussel cooking water decision scenario.

However, based on the limitations of the chosen AHP methodology there are a need for addressing these. The following is a recommended list of support tools that can be implemented into the WAHP tool and mitigate some of the general and tool specific limitations.

Recommendation for support tools to the WAHP tool

The WAHP currently operates under an equal weighting approach for each decision criteria with the option for the users to assign their own weights. Here a drawback in the current version of the WAHP is that when the user needs to assign their own weights manually in the tool as it does not provide a standardized approach to support the user in this activity. This may compromise one of the strengths "*An effortlessly decision support system for untrained users*" since can lead to too much manual work for the user who will also have to ensure that the new weights still add up to and don't exceed 1.0.

Here the implementation of a pair-wise comparison approach (Saaty, 1980)(as described in the previous section) to generate user weights for the main decision criteria that always adds up to 1.0 would be a recommendation for the WAHP tool to implement in future versions.

The value of the product after production and when it enters the market is not covered by the WAHP tool. This is a drawback in relation to the limitations "*Can't unravel non straight models*" and "*Can't consider uncertainty and dangers* ", because the economic assessment of the tool does not factor in how the market might react to the new product nor how big the market is. Currently the tool works of the assumption of how big the market is, and that the reception of consumers or B2B customers will be positive.

This is a rather important assumption about a key economic factor that needs to be addressed. An estimation of the market not grounded in a market analysis, risk analysis, or a price analysis runs the risk of exposing the economic results to *optimism bias* (Gilovich et al. 2002).

Therefore, it would be a recommendation that the user is being recommended to check the input values and conduct the prior mentioned analysis to ensure that the input values also reflect the real market situation as close as possible to reduce uncertainty regarding the input values and subsequent AHP scores. Alternatively, the designer of the tool does this instead for the user.

Another limitation of the WAHP is the "*issues with visualizing results*". A basic visualization of AHP scores can be viewed in table 2 below.

Alternative	**1. Technical viability (index 0-10)**	**2. Payback period (years)**	**3. ROI (1.000 € per Year)**	**4. Carbon footprint (kg CO_2/kg product)**	**5. Eutrophication (N/kg product)**	**6. Water footprint (m^3/ kg product)**
A	6.21	6.01	438.24	1,000.00	0.60	269.40
B	6.28	7.39	266.40	275.40	0.17	74.14
C	5.91	6.06	431.37	1,523.00	0.91	410.10
D	6.09	9.10	87.70	951.60	0.57	256.20
E	5.90	9.11	85.98	1,555.00	0.93	418.60
F	6.26	8.83	113.47	202.20	0.12	54.43
G	5.99	8.21	177.05	923.70	0.55	248.70

Table 2: AHP scores in an unmodified matrix only able to display the recommendation of one weighting set.

Here a user might be overwhelmed by the amount of information that is being presented and fail to intuitively identify which alternative should be chosen. Furthermore, this type of AHP score presentation is only for one weighting set and a new table would have to be created for each weighting set employed by the user. This would create a rather cumbersome comparison approach between different tables for the user, which may decrease its value as a decision support tool, simply because it does not provide a clear information overview.

To account for this, an implementation of the TOPSIS technique to create a single score system to help visualize the results of the AHP scores from the WAHP tool is recommended.

In brief, TOPSIS is a method used to compare a set of alternatives based on a pre-specified criterion. This method can be used when decision makers need to make an analytical decision on which alternative to select based on the collected data.

"*TOPSIS using the principle that the alternatives selected must have the shortest distance from the positive ideal solution and the farthest from the negative ideal solution from a geometrical point by using the Euclidean distance to determine the relative proximity of an alternative to the optimal solution.*" (Rahim et.al, 2018: 3).

The results of implementing TOPSIS in the setting of the WAHP tool can be viewed in table 3 below.

Alternative to choose	**TOPSIS Pi rating – Expert weights**	**TOPSIS Pi rating – Initial user weights**	**TOPSIS Pi rating – Debiased user weights**
A	0.55	**0.82**	0.61
B	**0.77**	0.56	**0.66**
C	0.38	0.73	0.56
D	0.35	0.14	0.26
E	0.00	0.00	0.06
F	0.64	0.29	0.48
G	0.41	0.29	0.36
Ranking based on Pi	**B**>F>A>G>C>D>E	**A**>C>B>F=G>D>E	**B**>A>C>F>G>D>E

Table 3: The final AHP score matrix displaying difference in recommendation between expert weights, user weights and debiased user weights using TOPSIS technique in the WAHP. Pi stands for Performance score.

Here the overview more cleanly conveys information to the user about which alternative should be chosen in a given decision scenario. It also enables a comparative setting where the AHP scores from different weighting sets can be listed and compared more easily by the user.

Support tool to account for the limitations "*Human cognition and emotions are obscure*" and "*Results are prone to subjectivity*" see the section "*Target 2: Description of the debias support tool as a supplement to the WAHP tool*" on the next page.

Sum-up target 1

Based on the MCDM tools overview with their associated strengths and limitations conducted in table 1, the selection of the AHP methodology in task 2.4 can be confirmed to be a suitable MCDM technique to apply to the supply chain study of mussel cooking water.

The other MCDM tools could also have been applied to the supply chain case, but their limitations, particularly the difficulty of use by a non-trained user is a major factor in the recommendation of utilizing the AHP methodology instead.

Despite its strengths are there several limitations to AHP methodology that should considered addressed by the design team of the WAHP tool in task 2.4 to ensure that the tool provides the most objective recommendation and user experience for the project companies in the WaSeaBi project.

The deliverable for target 1 "*Selection of decision tool in one supply chain and recommendation of support tools is based on task 2.5 in connection to the output*" has been completed.

Target 2: Description of the debias support tool as a supplement to the WAHP tool

In the milestone report 4, the methodology for the new support tool based on Cognitive Mapping method and Attribute Substitution to enable the identification of biases was addressed in detail.

Since then the method has been refined and can currently be viewed in the article manuscript "*Making the objectively best choice for side-stream resources - Verification of debiasing method based on cognitive maps and attribute substitution.*". The manuscript is currently in peer review for the journal Frontiers in Food Science and Technology. Feedback from the journals peer reviewers has as of writing this report (last edit 20/12 2022) been positive.

The manuscript for the submitted article and its supplementary material can be provided on request.

The deliverable for target 2 "*Development of a new support tool for the industries that ensure a more unbiased approach in the organizations."* has therefore been completed.

Table 4 contains an overview of the features of the new decision support tool outlined in the before mentioned manuscript for the article.

- Detailing the development of a novel method framework that accounts for the limitations "*Human cognition and emotions are obscure*" and "*Results are prone to subjectivity*" of the AHP tools. Also applicable in the WAHP tool mentioned in the previous section.
- The developed novel method framework is capable of identifying subjective cognitive biases from interview data through the analytic flow: Thematic analysis -> Cognitive Mapping with causal techniques -> Attribute Substitution analysis -> Identification of case specific biases -> Implementation of Debiasing techniques to reduce subjectivity.
- Testing of the analytical flow and debiasing techniques were applied to one of the project companies in the WaSeaBi project in a simulated decision scenario on side-stream utilization with cod filleting machine suppliers.
- The method proved successful in correcting for the rank reversal that can occur when strong subjective bias from the user causes the weighting set to favor only a few criteria. This favoring of a few decision criteria effectively rendered the other criteria in the WAHP tool without any influence on the alternative being recommended by the tool in this test.
- The subsequent sensitivity analysis of the developed method shows that the implemented debiasing techniques can consistently correct biased rankings and avoid overweighting alternatives that does not meet the decision objectives in given simulated scenarios.

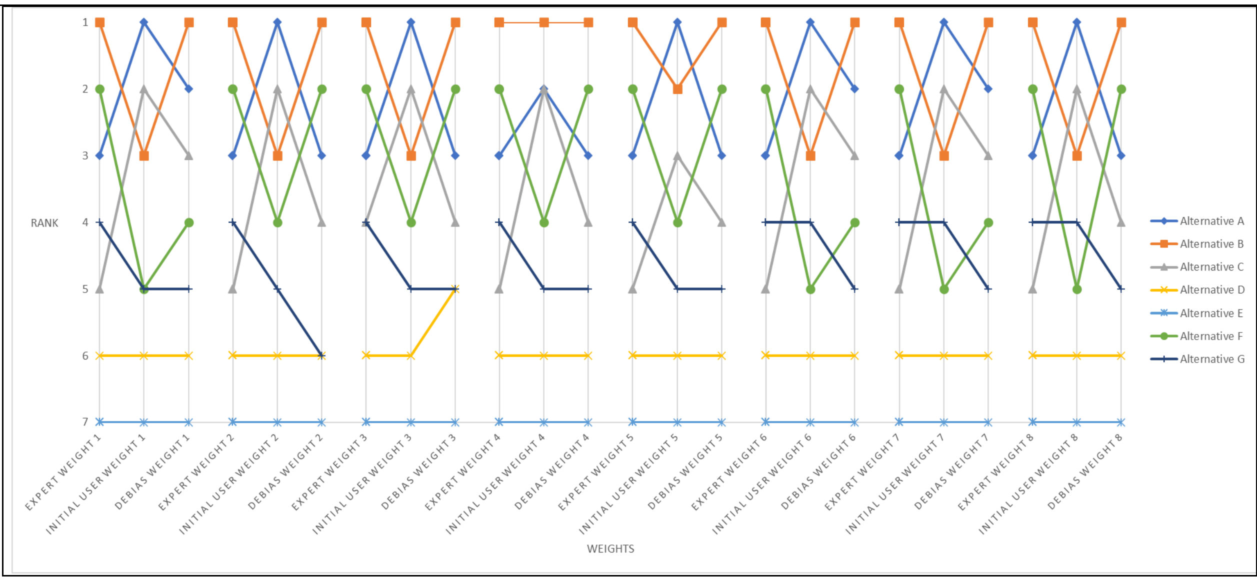


Figure 1: Sensitivity analysis of the decision tool. Alternatives B is the alternative that l should be recommended by the WAHP tool due to scenario design and based of experts weighting. Allowing for user edited weights causes a rank reversal that leads to alternative A being recommended instead, which is not desirable. Implementing relevant debiasing techniques corrects the ranking to once again recommend alternative B.

- The decision support tool has been designed to be generic, meaning that its application is not restricted to the context of the seafood industry. The only main restriction is if the company in question is using or is against using MCDM tools to support their decision process.

Table 4: The features of the developed decision support tool in task 2.5

Conclusion

The stated targets for deliverable 2.5 have been meet. The findings and results from target 2 have been implemented into the work being done in task 2.4 related to developing the WAHP.

The findings and recommendations in relation to target 1 have been relayed to the WAHP developers for they consideration in relation to the further development and refinement of the WAHP tool.

The findings and results on the identification of subjective biases from task 2.5 have also been communicated to the work package 4 leader to ensure a collaboration on the value navigator tool being developed in that work package, so it can account for information-oriented biases such as confirmation bias and omission bias.

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