

Navigating the waves during a global crisis: Overcoming challenges with pioneering solutions in multi-use offshore projects

Electronic Supplement

1. Principle notes on WSM and DCFM

This supplemental material provides further instructions and examples on how to use the Weighted Scoring Module (WSM) and the Discounted Cash Flow module (DCF) especially within the provided excel file. For the ease of understanding a few details of the main text are repeated.

Please note: Within this supplement the German notation for decimal points (comma) and thousand separators (point) are used to keep consistent with the provided excel file and screen shots of excel tables used hereafter. Example: 1.234,55 € reads: 1234 Euro and 55 cents. The excel file itself is also provided within the electronic supplements.

2. The project

Within this material a potential project has been selected as an example for the use of the WSM and DCFM. Four potential aquaculture species have been chosen for a closer inspection of their suitability: *Mytilus edulis* (blue mussel), *Ostrea edulis* (European oyster), *Oncorhynchus mykiss* (rainbow trout), and a macroalgae (*Saccharina latissima*). The location of the culture unit has been pre-selected and is linked to a remote offshore location (30km off the coast) in the southern North Sea.

3. Weighted Scoring Module (WSM)

The use of the WSM is the first step to initiate the decision process of selecting a species which seems to be most suited for the given location based on biological, technical and economic criteria. The construction of the WSM matrix should be left to the project team or an independent consultant supporting the team. However, filling in the values for the weighting of criteria and awarding actual points to the options the opinions of not only the project partners but also of additional stakeholder as well as experts might be needed. As in many situations of developing a decision process there is a trade-off between the quality of data (e.g. certainty of value assignment) and the costs and time required to involve additional external experts.

The WSM is constructed in 4 Steps, that will be exemplified via a simple decision module in our case of choosing a species for a given location. The following illustrated steps are pointing directly to Table S1.

Step 1: Find the criteria

First, from the list of **criteria** (Table S2, Column A) those criteria are chosen which are considered most relevant for evaluating the suitability of a species for the given location. Note that all those criteria that have an impact on investment, cost, risk and feasibility or are important for the project due to mandatory requirements should be selected. A discussion modus among stakeholders on how to select and prioritize criteria, see the respective references.^{1,2}

A top-down approach, involving a brainstorming session and benchmarking methods may be used to finally decide on a list of suitable criteria. Ultimately it is important to structure the criteria mutually exclusive and collectively exhaustive (MECE). Also, there should be not too many criteria. In most cases a total of up to 20 or even less would be fully sufficient. During testing one may find that one or another of the criteria do not make a difference in the overall outcome of the assessment. These can be omitted. It might also be useful to group several criteria (see Table S2, Rows 3, 11, 19) for a quick overview of the outcome and a clear structure of the results. In cases the WSM has been used *without* a separate financial calculation, the information on costs and revenues can be included in a second run of the WSM module.

However, If the WSM is used *parallel* to the DCFM, no financial information should be included in the WSM, as the WSM and the DCFM might yield conflicting results.

Step 2: Weighting the criteria

The criteria have to be **weighed** against each other, because very few of them will ever have the same importance for the decision process and thus may be assigned different values. One objective method for achieving a sound value for each criterion is to compare all criteria values: Decide for each match whether criterion “A” is more, less or equally important than criterion “B”. Two points are given for a criterion judged to be “more important than others”, only one for criteria of “equal” importance and zero for being considered “less important” compared to others.

Table S1 shows a simple example of relatively weighing of seven selected criteria just for the section “Biological suitability for location” (Table S2). This block of criteria has been given a total value of 30% by a priori decision making of the team that now have to be distributed across the seven criteria.

In theory, each weighting of the environmental factors should be consistent: in our example, „temperature” should be more important than “current” in weightings. Just let the team members vote on the matches and have a look whether the votes are consistent in both matches. If not, a further discussion might be advisable.

In the end all “points” awarded to a criterion (E.g. “temperature” in cells “B5:H5”, Table S1) are summed up (cell “J5”, Table S1) and transformed into percentages. For “Temperature” it is $11 / 42 * 30\% = 7,86\%$.

This step is **just for weighting** the criteria objectively; not to award points to a particular species.

Table S1 Example of possible Relative weighting of environmental criteria by a stakeholder team. Within column A and row 1 the criteria are listed. Each combination of two of the selected criteria is awarded either 2, 1 or 0 points. If a criterion in column A is more important than any of the other criteria in row 1, 2 points are awarded. If the criterion in column A is considered to be equally important to any other criterion in row 1, only 1 point is awarded. If the criterion in column A is less important, zero points are given.

	A	B	C	D	E	F	G	H	I	J	K
	2 = column A more important than row 1 = undecided/ tie 0 = Row 1 more important than column A	Oxygen level	Current	Sea level	Temperature	Risk of emissions	Chlorophyll a	Turbidity			
1										42	30%
2	Oxygen level	x	1	1	1	1	1	1		6	4,29%
3	Current	1	x	2	0	2	2	2		9	6,43%
4	Sea level	1	0	x	0	2	1	2		6	4,29%
5	Temperature	1	2	2	x	2	2	2		11	7,86%
6	Risk of emissions	1	0	0	0	x	1	1		3	2,14%
7	Chlorophyll a	1	0	1	0	1	x	1		4	2,86%
8	Turbidity	1	0	0	0	1	1	x		3	2,14%

Step 3: Choosing a scale and start awarding points

A scale for awarding points is chosen as an example, that is neither too detailed nor too coarse. In this example a scale of “1–10” was chosen. This scale is also often used in practice. Sometimes, also minimum values are fixed for some criteria; the species is rejected immediately if the value is below a predetermined number in one criterion. In the example case, only species that are eligible and passed the pre-selection are used, hence no threshold is needed.

Points are awarded to each species for each of the selected biological criteria. The points should be given in relative ratings so that options to rank species suitability are possible. However, if there is an apparent outlier value, this should not dominate the rest of the ratings. That means: If the “need for infrastructure” is low, more points should be awarded, since this makes the species attractive for the given location.

Note: Sometimes there is a “sweet spot for a criterion: This would lead to a concave shaped correlation between the criterion and points. They may not always be linear and sometimes not even monotonically. See a detailed discussion of this issue.³

Step 4: Calculating the overall score on various criteria sets

For each of the criteria sets (e.g. environmental, economic, biological and selected species), the points awarded to the criteria are multiplied horizontally with the weight of the criteria. This will result in a “score” that is then vertically summed up to deliver the total score of an option (Table S2).

Table S2 Matrix of the weighted scoring module for scoring of the four species “mussel”, “rainbow trout”, “macroalgae” and “oyster” at a fixed location according to different criteria, resulting in a final score

	A	B	C	D	E	F	G	H	I	J
1	species/scenario		mussel		rainbow		macroalgae		oyster	
2	criteria	weight	value	score	value	score	value	score	value	score
3	Environmental suitability for location	30%		6,93		5,98		7,83		7,40
4	Oxygen level	4,3%	9	0,39	1	0,04	10	0,43	9	0,39
5	Current	6,4%	6	0,39	9	0,58	9	0,58	6	0,39
6	Sea level	4,3%	6	0,26	1	0,04	6	0,26	8	0,34
7	Temperature	7,9%	7	0,55	8	0,63	5	0,39	7	0,55
8	Risk of emissions	2,1%	5	0,11	1	0,02	10	0,21	5	0,11
9	Chlorophyll a	2,9%	7	0,20	10	0,29	10	0,29	9	0,26
10	Turbidity	2,1%	9	0,19	9	0,19	9	0,19	9	0,19
11	General suitability for location	30%		5,70		3,11		5,95		5,77
12	Water depth	7,5%	5	0,38	1	0,08	5	0,38	5	0,38
13	Need for easy reachability	2,7%	9	0,25	2	0,05	9	0,25	8	0,22
14	Need for infrastructure	4,8%	7	0,33	5	0,24	6	0,29	7	0,33
15	Ease to obtain measurements	3,4%	4	0,14	4	0,14	8	0,27	4	0,14
16	Need for data	4,1%	5	0,20	5	0,20	5	0,20	5	0,20
17	Need to build additional structures	6,1%	5	0,31	3	0,18	5	0,31	6	0,37
18	Low need for Onshore base	1,4%	8	0,11	3	0,04	7	0,10	7	0,10
19	Economic and political suitability	40%		5,29		2,35		4,93		5,02
20	Investment needed (Capex)	3,6%	7	0,25	2	0,07	7	0,25	6	0,22
21	Operational expenses (Opex)	3,6%	7	0,25	2	0,07	6	0,22	7	0,25
22	Robustness of scenario	7,3%	5	0,36	2	0,15	3	0,22	4	0,29
23	Revenues	1,5%	3	0,04	3	0,04	5	0,07	7	0,10
24	Stakeholder acceptance	4,4%	9	0,39	3	0,13	8	0,35	9	0,39
25	Likelihood to obtain permit (environmental)	8,0%	5	0,40	3	0,24	6	0,48	5	0,40
26	Likelihood to obtain permit (construction)	2,9%	5	0,15	2	0,06	4	0,12	3	0,09
27	Likelihood to obtain insurance	8,7%	3	0,26	2	0,17	3	0,26	3	0,26
28	Sum	100%		5,91		3,67		6,11		5,96

The following steps represented in Table S2 can be further explained as follows:

- (Table S2, cells A3:A27) The criteria are derived from the demands requested by the stakeholder and what has been identified as important for the overall success of the project via brainstorming sessions (bottom up) and a logical deduction process (top down).
- (Table S2, column B, cells B13:B27) The weights are derived from a comparison of criteria, and the assigned values are transformed into a 100% scale. Thus, weighting should finally be expressed in percentages and not in absolute numbers in order to avoid abstracting high numbers in the final score, see also table S1.
- (Table S2, cells C1:J2) pre defined eligible species are entered in row 1 with a cell for the assigned points and for the resulting weighted “score” of each category.
- (Table S2, cells C4:C27) The points for each criterion are awarded according to knowledge base and informed decisions by the team or by input from additional advisors.
- (Table S2, cells D4:D27) The points are multiplied with the weight, resulting in the score. For example, oyster was awarded seven points on the criteria of “temperature”. These points are weighted with 7,9 % of the criterion. $0,079 * 7 = 0,55$.
- The above mentioned steps will have to be done for all other criteria for the selected species “oyster” (column J). Finally, all the weighted scores in the cells of column “J” are summed up to derive at the final score, of 5,96 (oyster scenario). The summation of values in cells D, F, H, J, 3 are calculated automatically.
- (Table S2, cells E3:H23) These operations are repeated for all other three selected species.

In this case example the macroalgae species seems to provide the best option for aquaculture at the given location, but not by a wide margin. A careful look at the values is hence advisable.

4. Financial calculation via a discounted cash flow module (DCFM)

Having chosen the macroalgae (for example) for the given location a detailed financial calculation is needed for the implementation of the project. It can be used to calculate the funding needs. Using a net present value method to discount future payment surpluses (or deficits).

In a nutshell the DCFM can be described as noting down all positions taking cash out and bringing cash into the project, while calculating the yearly balance, and applying a discount of balances for future years. Finally, the discounted balances are summed up. For details of the processes involved see also Geisler⁴ Table S3 provides an overview of the results of the DCFM.

Table S3 Result table of the DCFM for the example project. Note that different sublevels are underlying the final excel sheet (represented by numbers 1 to 4 and plus and minus signs on the left-hand side of the table)

1	2	3	4	A	B	C	D	E	F	G	H
1	1					Source/ calculation	0 year	1 year	2 year	3 year	Parameter
	2				Investment & One Time	3+30+61+62	277.697 €	0 €	0 €	142.604 €	
+	3				Labor cost/ Service/ Logistics	4+17+20+24+27	217.947 €				
+	30				Building Material	31 + 34 + 37 + 40 + 43					
	61				Modifikation of existing location	+50 +53	39.750 €				
+	62				Disassembly	a	20.000 €				
	91									142.604 €	
-	92				Operational Cost	93 + 105 +108 + 109	227.531 €	235.566 €	236.254 €	236.475 €	
	93				Personell cost	+110 + 111 + 116					
+	105				Ship for work in offshore waters	94 + 98 + 102	104.031 €	110.566 €	110.616 €	110.669 €	
+	108				Replacement of modules	106 * 107	60.000 €	60.000 €	60.000 €	60.000 €	
-	109				Rent using existing onshore facilities	j, s		8.500 €	8.925 €	9.371 €	5%
-	110				Marketing/ PR	j, s		20.000 €	20.000 €	20.000 €	
+	111				Maintanace, replacements, operations material (MRO)	u	4.250 €	4.463 €	4.686 €		
+	116				Logistics and transport (Helicopter)	sum 112:115	4.000 €	2.500 €	2.500 €	2.000 €	
	120					117 * 118 * 119	59.500 €	29.750 €	29.750 €	29.750 €	
-	121				Cash in	122 + 125	0 €	25.500 €	25.500 €	25.500 €	
+	122				Revenue mussels	123 * 124	0 €	25.500 €	25.500 €	25.500 €	
	125				Other sources		0 €	0 €	0 €	0 €	
	126				Balance	127 - 128	-505.228 €	-210.066 €	-210.754 €	-353.580 €	
	127				Cash out (onetime and running)	2 + 92	505.228 €	235.566 €	236.254 €	379.080 €	
	128				Cash In (revenues)	121	0 €	25.500 €	25.500 €	25.500 €	
	129										10%
	130				Discount factor	1 / (1 + Interes rate)					
	131				Discounted Balance	^ year	1,00	0,91	0,83	0,75	
	132				Net present Value	126 * 130	-505.228 €	-190.969 €	-174.176 €	-265.650 €	
							-505.228 €	-696.197 €	-870.374 €	-1.136.023 €	

Horizontal structure (columns)

Horizontally the different positions (cost, revenues) are listed in column B. To make clear calculations unique row numbers were added in column A. Since positions (criteria) might have to be added later during the implementation of the project, these items will be assigned a new running number at the end of the Excel master sheet. Therefore, this prevents changing Excel row-numbers. Column C identifies the sources of the assigned values. There are basically two sources:

Firstly, the source is a value identified by an external party, e.g. an actual offer for materials/equipment by a vendor. Sources might be specifically and individually added to each value. In this example we coded the external parties with a, b, c, d, j, s, u. The sources can be contacted later on to verify or to adapt the figures.

Secondly the source is represented by a calculation for covering several items, e.g. summing up all the costs on the various positions of personnel or multiplying costs with the number of resources used such as divers *, days needed for diving trips * as well as price per diver per day to reflect the total costs of all diving activities during the project phase.

Starting with column D (year zero) and E, F, G, the years thereafter, the calculated values for each year are presented. A “Year” is usual the smallest administrative unit to be entered in cost value. However, columns can be added (sub-divided) to accommodate quarters or even months if higher time resolutions are needed. This would allow a tighter view and grip on the cash flow. NOTE: In short-term projects there is apparently no need to apply discount rates or employ a net present value method.

The vertical structure

The vertical structure of the DCFM is basically divided into three separate blocks: Cash outs (costs), Cash in (revenues) and the yearly balance incorporating discount factors if applicable.

Block 1: Cash Outs Positions

There are two different kinds of cash out positions that should be accounted for separately: First there is the so-called “one-time”- investment, such as construction material and labor cost for the installation work, in another economic context also often named CAPEX (Capital expenditure). Thereafter the operating expenditures (OPEX) are listed that will have to be paid for on a regular basis such as rent of a facility or outsourced and irregularly needed services. Although the separation of the two cash out positions is not relevant, the timeframe for payments is relevant and affects the financial management of a project. It is usually expected to group one-time expenditures and operational

expenses in the financial accounting scheme.

Taking a closer look at some details within the investment/ onetime cash out positions (table S4), the structure is always similar: Single cost positions, e.g. the underwater installation cost by divers (cell D17, table S4) are calculated by multiplying the number of days needed for diving sessions (cell D18,table S4) with the price per day required to cover costs for work under water (e.g. installation of or service work on units)(cell D19, table S4). This is necessary to estimate the impact of different risks of potential cost implications separately. There might be the risk that it takes more days for underwater work than the initial forecast of two days has assumed, or the prices for specific materials and work might have gone up shortly after the initial assessment. This assignment flexibility is applied to all other cost positions (indicated in Table S4, by the notations “+” or “-“within the master Excel file.

For every item in column B (Tabel S4), the subsequent column (C) identifies the sources/services involved by its respective code number. The total labor cost/ service/ logistics is the summation of lines 4, 17, 20, 24 and 27. If a value is not yet assigned, the item still must have an ultimate source, e.g. a real offer by a commercial service but may become relevant only later during the project but an overall estimate is tentatively inserted as can be seen in Cell D19 (Table S4), indicating 13.388 € (marked in red) Thus, these mostly supplemental materials are marked by the notations “a” and “b” representing different vendors.

Table S4 Some details of the different cash flow positions used for calculation of investment and one time cost summarized under “Labor cost, service and logistics” (cells A4:A27).

1	2	3	4	5	A	B	C	D	E	F
							Source/ calculatio	0 year	1 year	2 year
	1	1								
	2	2				Investment & One Time	3+30+61+62	277.697 €	0 €	0 €
	3	3				Labor cost/ Service/ Logistics	4+17+20+24+27	217.947 €		
	4	4				Ship charter cost	5 + 8 + 11 +14	83.995 €		
	17	17				Installation cost (divers)	18 * 19	26.776 €		
	18	18				Days under water	a	2		
	19	19				€ per das under Water	b	13.388 €		
	20	20				Persoonell cost planning	21 * 22 * 23	92.466 €		
	21	21				months planning	a, d	6		
	22	22				number of planners	a, d	3		
	23	23				€ per planner per month	e	5.137 €		
	24	24				Transport cost by helicopter	25 * 26	11.330 €		
	27	27				Training offshore personell	28 * 29	3.380 €		
	30	30				Building Material	+43 +50 +53	39.750 €		
	31	31				Longlines cost		1.200 €		
	34	34				Anchor blocks cost		1.200 €		
	37	37				Anchor chain cost		10.800 €		

Block 2: Cash-In Position

Project components funded by public and private investors are not accounted for this block of lines. In the calculation of research projects there are usually no or few revenues generated. In this example project, revenues are created by selling mussels. This position is the product of the price of mussels multiplied number of mussels harvested. It is advisable not to assume harvesting during installation and to estimate revenues conservatively, especially within the first years.

Block 3: The balance of cash-in and cash-out positions

This block does not represent a complete “financial balance sheet “. This block can be modified if appropriate. As mentioned above the revenues or deficits can be presented in greater details and subcategories inserted. This will only need adding lines for specific components or adding columns for quarter years or even months. For example, the yearly balance in row 126 (Table S5) represents the total annual financial input needed to run the exemplified project in this study.

Table S5 Block 3, of the DCFM, showing the overall balance in some detail. Column B represents the starting year (year 0 of Table S3 and S4) and the columns thereafter refer to the subsequent project years

	1	2	3	4	5	A	B	C	D	E	F	G	H	I
	126	126					Balance	127 - 128	-505.228 €	-210.066 €	-210.754 €	-353.580 €		
	127	127					Cash out (onetime and running)	2 + 92	505.228 €	235.566 €	236.254 €	379.080 €		
	128	128					Cash In (revenues from mussel sales)	121	0 €	25.500 €	25.500 €	25.500 €		
	129	129					Net present Value (cumulated)		-505.228 €	-696.197 €	-870.374 €	-1.136.023 €		
	130						Discount factor	1 / (1 + Interest rate) ^ year	1,00	0,91	0,83	0,75	10%	Interest rate
	131						Discounted Balance	126 * 130	-505.228 €	-190.969 €	-174.176 €	-265.650 €		

After preparing the balance calculations, the discount factors are added (row 130 and row 131, Table S5). This item addresses a very important issue for commercial projects as the factor incorporates an interest rate or hurdle rate and acknowledges the fact that financial returns in the future a) may be uncertain or b) could otherwise also be invested instead of counting them as revenues. The nominal face value of each year in row 126 (Table S5) is multiplied with the discount factor in row 130 (Table S5) and will thus result in the discounted Cash flow presented in row 131 (Table S5). The discount factor is calculated as:

$$1/(1 + \text{interest rate})^{\text{year from now}},$$

starting with the first (or current) year. For a detailed discussion of the net present value method please see also.^{2,5,6}

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