Multi Criteria Decision Making (MCDM)

➢ ENTROPY METHOD

The **Entropy method** is a weighting technique used in MCDM to objectively determine the weights of criteria. In MCDM, different criteria may have varying degrees of importance, and the Entropy method calculates these weights based on the information contained in each criterion's data.

Step 1 Creating the initial decision matrix: The decision alternatives of the problem and the evaluation criteria to be considered while evaluating these alternatives are determined. Then, the initial deci-

Factors	Decarbonization	Regulatory Co	Opportunity c	Impact on the	Safety	Global Availa	Supply Capaci	Durability	Adaptability	Fuel availabil	Vessel Safety	Reliability	Energy storage	Infrastructure	Air pollution	Acquisition co	GHG Emission	Technical mat	Capital Cost	Public acceptance
Decarbonization	6	3.75	3.25	4.75	3.75	3.5	3.5	2.75	3.25	3.75	3.25	3.25	3.25	3.5	4.25	3	4.25	3.25	2.5	3.5
Regulatory Compliance	3.75	6	3.25	2.75	3.75	3	3	3.25	3.5	3.5	3.75	3.75	3.25	3.25	4	3.25	3.75	3.5	3.25	3.25
Opportunity cost	3.5	3	6	3	3	3.25	3.5	2.5	3.25	3	3.25	2.75	2.5	2.75	3	3.25	3	3.5	3.5	3
Impact on the ecosystem	4.75	3	3.25	6	4	3.75	3	3.75	3	3.5	3.75	3	3	3.5	4.5	2.5	4.25	3.25	2.75	3.25
Safety	3.5	3.75	3	4.25	6	2.75	2.5	3.75	3.75	3.5	4.75	4	3.75	3.5	3.5	2.75	3.75	3.5	3	3.75
Global Availability	3.75	3.25	3.5	3.75	2.75	6	4	3	3	4.25	3.5	3.25	3	3.5	2.5	2.75	2.5	3	3.25	3.25
Supply Capacity	3.5	3.25	3.25	3	2.5	3.75	6	3	3.5	4	3.75	3.75	3.25	3.75	2.75	3.25	2.5	3.5	3.25	3
Durability	2.75	3.25	3	3.5	4	3	2.75	6	3.5	2.75	4	4	3.5	3.75	3.5	3.25	3	3.5	3.5	3.75
Adaptability	3.75	3.5	3.75	3.5	3.5	3.25	3.5	3.5	6	3	4	4	3.5	3.75	3	3	3.25	4.25	3	3.75
Fuel availability	3.75	3.5	3.25	4	4	4.25	3.5	3	3.5	6	3.75	3.5	3.5	3.75	3.75	2.75	3.75	3.25	3.25	3
Vessel Safety	3.5	4.25	3	4	4.5	3.5	3.5	3.75	4	4.25	6	3.75	3.75	3.5	3.75	3.25	3.5	3.5	3.5	4.25
Reliability	3.75	4	3	3.5	4.25	2.75	3.5	3.75	3.5	4.25	4	6	3.75	3.75	4.25	2.75	3.75	4	3	3.5
Energy storage efficiency	3.5	3.25	3	3.25	3.75	3	3.75	3.75	3.75	4	3.75	3.75	6	4	3	3	2.75	3.75	3.75	3.75
Infrastructure	3.5	3.25	3	3.25	3.75	3.25	4	4	4	3.5	3.25	3.5	3.75	6	3.25	3.25	3.5	3.5	3.25	3.75
Air pollution	4.75	4	3.25	4.75	3.75	3	2.75	3.25	3.75	4	3.75	3.5	3.25	3	6	3	4.25	3.5	3.25	3.75
Acquisition cost	3.25	3	3.25	2.75	2.75	2.75	3.25	2.75	3.25	3	3	2.75	3	3.25	3.25	6	3.5	2.75	3.75	3.25
GHG Emission reduction	4.25	4	3.25	4.25	3.75	2.5	2.75	3.5	3.5	3.75	3.25	3.5	2.75	3.25	4.25	3	6	3.75	3	3.5
Technical maturity	3.25	4	3.25	3.25	3.5	3.25	3.5	3.5	3.75	3.5	3.5	3.75	3.75	3.75	3.5	3	3.5	6	3.25	3.5
Capital Cost	2.75	3.25	4.25	2.75	3.25	3.25	4	3.25	3.25	3.25	3.5	2.5	3.5	3.5	3.5	3.75	3.25	3.25	6	3.75
Public acceptance	3.5	3.5	3	3.5	3.75	3.5	3	3.25	3.25	3	3.75	3.5	3.75	3.5	3.5	3.25	3.25	3.5	3.25	6

Step 2 Normalizing the initial decision matrix: The values of the criteria that have different units in the problem are normalized with the help of Eq. (2) and converted to values in the range of [*0, 1*].

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{2}$$

Factors	Decarbonizati	Regulatory	Opportuni	Impact on	Safety	Global Ava	Supply Cap	Durability	Adaptabilit	Fuel availa	Vessel Saf	Reliability	Energy sto	Infrastruct	Air polluti	Acquisition	GHG Emiss	Technical	Capital Co	Public acceptance
Decarbonization	0.08	0.051546	0.04797	0.064407	0.050505	0.052045	0.050542	0.039711	0.044983	0.050847	0.043046	0.045296	0.046595	0.048276	0.058219	0.046875	0.059649	0.045139	0.037175	0.0482759
Regulatory Compliance	0.05	0.082474	0.04797	0.037288	0.050505	0.04461	0.043321	0.046931	0.048443	0.047458	0.049669	0.052265	0.046595	0.044828	0.054795	0.050781	0.052632	0.048611	0.048327	0.0448276
Opportunity cost	0.04666667	0.041237	0.088561	0.040678	0.040404	0.048327	0.050542	0.036101	0.044983	0.040678	0.043046	0.038328	0.035842	0.037931	0.041096	0.050781	0.042105	0.048611	0.052045	0.0413793
Impact on the ecosystem	0.06333333	0.041237	0.04797	0.081356	0.053872	0.055762	0.043321	0.054152	0.041522	0.047458	0.049669	0.041812	0.043011	0.048276	0.061644	0.039063	0.059649	0.045139	0.040892	0.0448276
Safety	0.04666667	0.051546	0.04428	0.057627	0.080808	0.040892	0.036101	0.054152	0.051903	0.047458	0.062914	0.055749	0.053763	0.048276	0.047945	0.042969	0.052632	0.048611	0.04461	0.0517241
Global Availability	0.05	0.044674	0.051661	0.050847	0.037037	0.089219	0.057762	0.043321	0.041522	0.057627	0.046358	0.045296	0.043011	0.048276	0.034247	0.042969	0.035088	0.041667	0.048327	0.0448276
Supply Capacity	0.04666667	0.044674	0.04797	0.040678	0.03367	0.055762	0.086643	0.043321	0.048443	0.054237	0.049669	0.052265	0.046595	0.051724	0.037671	0.050781	0.035088	0.048611	0.048327	0.0413793
Durability	0.03666667	0.044674	0.04428	0.047458	0.053872	0.04461	0.039711	0.086643	0.048443	0.037288	0.05298	0.055749	0.050179	0.051724	0.047945	0.050781	0.042105	0.048611	0.052045	0.0517241
Adaptability	0.05	0.04811	0.055351	0.047458	0.047138	0.048327	0.050542	0.050542	0.083045	0.040678	0.05298	0.055749	0.050179	0.051724	0.041096	0.046875	0.045614	0.059028	0.04461	0.0517241
Fuel availability	0.05	0.04811	0.04797	0.054237	0.053872	0.063197	0.050542	0.043321	0.048443	0.081356	0.049669	0.04878	0.050179	0.051724	0.05137	0.042969	0.052632	0.045139	0.048327	0.0413793
Vessel Safety	0.04666667	0.058419	0.04428	0.054237	0.060606	0.052045	0.050542	0.054152	0.055363	0.057627	0.07947	0.052265	0.053763	0.048276	0.05137	0.050781	0.049123	0.048611	0.052045	0.0586207
Reliability	0.05	0.054983	0.04428	0.047458	0.057239	0.040892	0.050542	0.054152	0.048443	0.057627	0.05298	0.083624	0.053763	0.051724	0.058219	0.042969	0.052632	0.055556	0.04461	0.0482759
Energy storage efficiency	0.04666667	0.044674	0.04428	0.044068	0.050505	0.04461	0.054152	0.054152	0.051903	0.054237	0.049669	0.052265	0.086022	0.055172	0.041096	0.046875	0.038596	0.052083	0.055762	0.0517241
Infrastructure	0.04666667	0.044674	0.04428	0.044068	0.050505	0.048327	0.057762	0.057762	0.055363	0.047458	0.043046	0.04878	0.053763	0.082759	0.044521	0.050781	0.049123	0.048611	0.048327	0.0517241
Air pollution	0.06333333	0.054983	0.04797	0.064407	0.050505	0.04461	0.039711	0.046931	0.051903	0.054237	0.049669	0.04878	0.046595	0.041379	0.082192	0.046875	0.059649	0.048611	0.048327	0.0517241
Acquisition cost	0.04333333	0.041237	0.04797	0.037288	0.037037	0.040892	0.046931	0.039711	0.044983	0.040678	0.039735	0.038328	0.043011	0.044828	0.044521	0.09375	0.049123	0.038194	0.055762	0.0448276
GHG Emission reduction	0.05666667	0.054983	0.04797	0.057627	0.050505	0.037175	0.039711	0.050542	0.048443	0.050847	0.043046	0.04878	0.039427	0.044828	0.058219	0.046875	0.084211	0.052083	0.04461	0.0482759
Technical maturity	0.04333333	0.054983	0.04797	0.044068	0.047138	0.048327	0.050542	0.050542	0.051903	0.047458	0.046358	0.052265	0.053763	0.051724	0.047945	0.046875	0.049123	0.083333	0.048327	0.0482759
Capital Cost	0.03666667	0.044674	0.062731	0.037288	0.043771	0.048327	0.057762	0.046931	0.044983	0.044068	0.046358	0.034843	0.050179	0.048276	0.047945	0.058594	0.045614	0.045139	0.089219	0.0517241
Public acceptance	0.04666667	0.04811	0.04428	0.047458	0.050505	0.052045	0.043321	0.046931	0.044983	0.040678	0.049669	0.04878	0.053763	0.048276	0.047945	0.050781	0.045614	0.048611	0.048327	0.0827586

Step 3 Calculating the entropy values of the criterion: e_{ij} is the value corresponding to the uncertainty measure of the criterion j, or in other words the entropy value, is calculated with the help of Eq. (3). Here, k represents a constant coefficient defined as $k = (ln(m))^{-1}$ and e_{ij} is $0 \leq e_{ij} \leq 1$.

$$e_{ij} = -k \bullet \sum_{j=1}^{n} P_{ij} \bullet ln(P_{ij}) \quad (3)$$

m is alternative (Factors)	
m	20

Pij*ln(Pij)

Factors	Decarbonizat	Regulatory	Opportuni	Impact on	Safety	Global Ava	Supply Cap	Durability	Adaptabili	Fuel availa	Vessel Saf	Reliability	Energy sto	Infrastruct	Air polluti	Acquisitior	GHG Emiss	Technical	Capital Co	Public acceptance
Decarbonization	-0.20205829	-0.15285	-0.14569	-0.17664	-0.15079	-0.15383	-0.15086	-0.12811	-0.13951	-0.15147	-0.1354	-0.14017	-0.14287	-0.14632	-0.16555	-0.14345	-0.16817	-0.13984	-0.12238	-0.1463156
Regulatory Compliance	-0.14978661	-0.2058	-0.14569	-0.12264	-0.15079	-0.13873	-0.13599	-0.14357	-0.14665	-0.14465	-0.14912	-0.15426	-0.14287	-0.13919	-0.15913	-0.15134	-0.15497	-0.147	-0.14642	-0.1391866
Opportunity cost	-0.14302051	-0.13148	-0.21468	-0.13025	-0.12965	-0.14642	-0.15086	-0.11991	-0.13951	-0.13025	-0.1354	-0.12501	-0.11931	-0.12411	-0.13117	-0.15134	-0.13337	-0.147	-0.15383	-0.131792
Impact on the ecosystem	-0.17475842	-0.13148	-0.14569	-0.20412	-0.15737	-0.16097	-0.13599	-0.1579	-0.1321	-0.14465	-0.14912	-0.13273	-0.13532	-0.14632	-0.17176	-0.12666	-0.16817	-0.13984	-0.13072	-0.1391866
Safety	-0.14302051	-0.15285	-0.13803	-0.16445	-0.20329	-0.13072	-0.11991	-0.1579	-0.15355	-0.14465	-0.17402	-0.16094	-0.15716	-0.14632	-0.14564	-0.13523	-0.15497	-0.147	-0.13873	-0.1531981
Global Availability	-0.14978661	-0.13886	-0.15307	-0.15147	-0.12207	-0.21561	-0.1647	-0.13599	-0.1321	-0.16445	-0.14238	-0.14017	-0.13532	-0.14632	-0.11555	-0.13523	-0.11754	-0.13242	-0.14642	-0.1391866
Supply Capacity	-0.14302051	-0.13886	-0.14569	-0.13025	-0.11418	-0.16097	-0.21192	-0.13599	-0.14665	-0.15807	-0.14912	-0.15426	-0.14287	-0.1532	-0.12352	-0.15134	-0.11754	-0.147	-0.14642	-0.131792
Durability	-0.12121586	-0.13886	-0.13803	-0.14465	-0.15737	-0.13873	-0.12811	-0.21192	-0.14665	-0.12264	-0.15565	-0.16094	-0.15014	-0.1532	-0.14564	-0.15134	-0.13337	-0.147	-0.15383	-0.1531981
Adaptability	-0.14978661	-0.14598	-0.16019	-0.14465	-0.14399	-0.14642	-0.15086	-0.15086	-0.20665	-0.13025	-0.15565	-0.16094	-0.15014	-0.1532	-0.13117	-0.14345	-0.14084	-0.16703	-0.13873	-0.1531981
Fuel availability	-0.14978661	-0.14598	-0.14569	-0.15807	-0.15737	-0.17452	-0.15086	-0.13599	-0.14665	-0.20412	-0.14912	-0.14734	-0.15014	-0.1532	-0.1525	-0.13523	-0.15497	-0.13984	-0.14642	-0.131792
Vessel Safety	-0.14302051	-0.16592	-0.13803	-0.15807	-0.1699	-0.15383	-0.15086	-0.1579	-0.16021	-0.16445	-0.20125	-0.15426	-0.15716	-0.14632	-0.1525	-0.15134	-0.14803	-0.147	-0.15383	-0.1662874
Reliability	-0.14978661	-0.15949	-0.13803	-0.14465	-0.16373	-0.13072	-0.15086	-0.1579	-0.14665	-0.16445	-0.15565	-0.20751	-0.15716	-0.1532	-0.16555	-0.13523	-0.15497	-0.16058	-0.13873	-0.1463156
Energy storage efficiency	-0.14302051	-0.13886	-0.13803	-0.13758	-0.15079	-0.13873	-0.1579	-0.1579	-0.15355	-0.15807	-0.14912	-0.15426	-0.21102	-0.15985	-0.13117	-0.14345	-0.12562	-0.1539	-0.16097	-0.1531981
Infrastructure	-0.14302051	-0.13886	-0.13803	-0.13758	-0.15079	-0.14642	-0.1647	-0.1647	-0.16021	-0.14465	-0.1354	-0.14734	-0.15716	-0.20622	-0.13854	-0.15134	-0.14803	-0.147	-0.14642	-0.1531981
Air pollution	-0.17475842	-0.15949	-0.14569	-0.17664	-0.15079	-0.13873	-0.12811	-0.14357	-0.15355	-0.15807	-0.14912	-0.14734	-0.14287	-0.13179	-0.20537	-0.14345	-0.16817	-0.147	-0.14642	-0.1531981
Acquisition cost	-0.1360161	-0.13148	-0.14569	-0.12264	-0.12207	-0.13072	-0.14357	-0.12811	-0.13951	-0.13025	-0.12817	-0.12501	-0.13532	-0.13919	-0.13854	-0.22192	-0.14803	-0.12471	-0.16097	-0.1391866
GHG Emission reduction	-0.16266558	-0.15949	-0.14569	-0.16445	-0.15079	-0.12238	-0.12811	-0.15086	-0.14665	-0.15147	-0.1354	-0.14734	-0.12748	-0.13919	-0.16555	-0.14345	-0.20837	-0.1539	-0.13873	-0.1463156
Technical maturity	-0.1360161	-0.15949	-0.14569	-0.13758	-0.14399	-0.14642	-0.15086	-0.15086	-0.15355	-0.14465	-0.14238	-0.15426	-0.15716	-0.1532	-0.14564	-0.14345	-0.14803	-0.20708	-0.14642	-0.1463156
Capital Cost	-0.12121586	-0.13886	-0.1737	-0.12264	-0.13695	-0.14642	-0.1647	-0.14357	-0.13951	-0.13758	-0.14238	-0.11697	-0.15014	-0.14632	-0.14564	-0.16624	-0.14084	-0.13984	-0.21561	-0.1531981
Public acceptance	-0.14302051	-0.14598	-0.13803	-0.14465	-0.15079	-0.15383	-0.13599	-0.14357	-0.13951	-0.13025	-0.14912	-0.14734	-0.15716	-0.14632	-0.14564	-0.15134	-0.14084	-0.147	-0.14642	-0.2062202

SUM Pij*ln(Pij)	-2.97878127	-2.98092	-2.97911	-2.97368	-2.97747	-2.97511	-2.97577	-2.97711	-2.98297	-2.9791	-2.983	-2.97836	-2.9788	-2.98293	-2.9758	-2.97584	-2.97482	-2.98194	-2.9784	-2.9822795
Eij	0.99434161	0.995057	0.99445	0.992637	0.993903	0.993115	0.993338	0.993785	0.995739	0.994448	0.995749	0.994201	0.994349	0.995727	0.993346	0.993359	0.993018	0.995395	0.994214	0.9955094

Step 4 Finding the degrees of differentiation: Using the entropy values of the criteria, d_j values are calculated for each criterion with the help of Eq. (4).

$$d_j = 1 - e_j \tag{4}$$

dj	0.005658	0.0049	0.0056	0.0074	0.0061	0.0069	0.0067	0.0062	0.0043	0.0056	0.0043	0.0058	0.0057	0.0043	0.0067	0.0066	0.007	0.0046	0.0058	0.00449

sum dj	0.11431984

Weight(Wj)	0.049496	0.0432	0.0486	0.0644	0.0533	0.0602	0.0583	0.0544	0.0373	0.0486	0.0372	0.0507	0.0494	0.0374	0.0582	0.0581	0.0611	0.0403	0.0506	0.03928

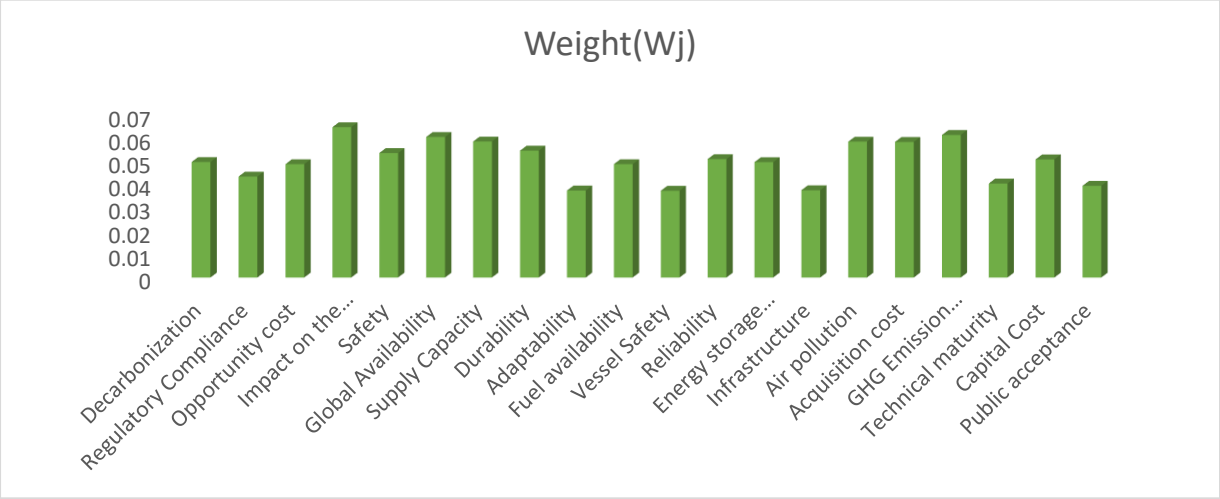

Figure 1. Figuring out the criteria the entropy weights

The entropy weights in the given figure show in figure 1 which factors have the highest weights and which have the least. From this figure we can draw the conclusion which are the factors which will have the greatest impact in the maritime industry at the time of adopting alternative fuel.