# Multiobjective Optimization of Floating Observational Buoys location/allocation for limiting marine pollution impact caused by hydrocarbons release

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*Abstract:* - The use of meteorological stations may be helpful in assessing climatic and meteorological data in a marine environment. But for the accuracy and reliability of the data obtained, the measurements should take place at appropriate locations on or near the sea surface. For this purpose, Floating Observational Buoys (FOBs) are widely used for the collection of such meteorological and climatological data as well as for the concentration of polluting substances like crude oil and hydrocarbon mixtures produced in oil refineries, causing systematic or accidental pollution. Therefore, it is clear that the optimal location of installation points should be based on specific criteria covering all aspects / objectives of this large scale monitoring operation.
In the present work, we have developed a new two-phase version of the multiobjective Analytic Hierarchy Process (AHP) for selecting optimal location points for FOBs installation to collect the relevant data from marine areas, mainly based on the following criteria: the average wind speed, the waves characteristics, the vulnerability of coastline, the probability of maritime accidents. This version of AHP is implemented in several marine areas of the Aegean Sea, especially along the corridor between the Greek islands and the Turkish continental coast. The solution of the location / allocation problem is examined through sensitivity / robustness analysis and the final results, concerning optimization of Buoys Network within certain Greek marine areas, are further discussed.

*Key-Words:* - Multiobjective Analysis, Hydrocarbons release, Marine Pollution, Buoys Network

## 1 Introductory Analysis

Hydrocarbons release in marine environment may occur by accident or by intention through de-ballasting and waste oil discharge (routine/ systematic release). The oil spill created by accident undergoes physical and biochemical transformation, including dispersion and weathering, which is a complex process that consists of dissolution, emulsification, evaporation, adsorption, flotation, flocculation / aggregation / sedimentation, and bio-degradation. The situation becomes more complicated when a chemical dispersant is added, contributing to the formation of colloidal dispersion by lowering the oil-water interfacial tension [1-4].

For limiting/mitigating the marine pollution impact, we may use Floating Observational Buoys (FOBs) for early warning since the route of oil spill expected to follow and the time required to reach the coastline is of critical importance.

The optimal number $N_{opt}$ of FOBs can be determined by minimizing the environmental information acquisition cost $C(N) = C_1(N) + C_2(N)$, where $C_1$ and $C_2$ are partial costs opposing to each other, thus forming a trade-off. The former depends on accessibility and maintainability of each additional FOB; this dependent variable is an increasing function of N with an increasing rate (i.e., $dC_1 / dN > 0$), since the FOBs established first

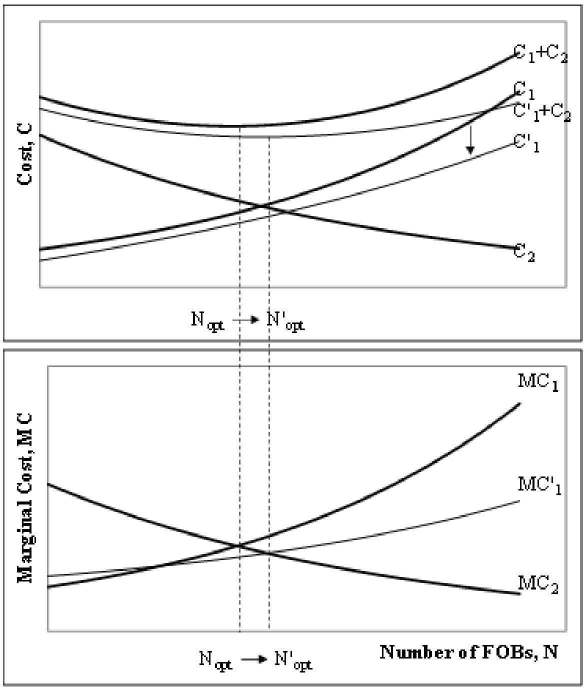


**Fig. 1a.** Dependence of partial costs $C_1$ and $C_2$ on the number of FOBs N and shifting of $N_{opt}$ in case of introducing into the network a new large floating platform, properly equipped.

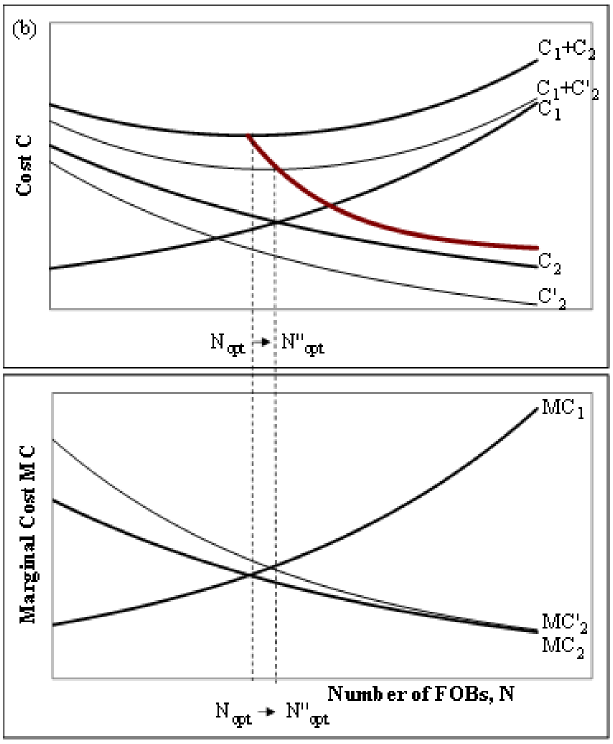


**Fig. 1b.** Dependence of partial costs $C_1$ and $C_2$ on the number of FOBs N and shifting of $N_{opt}$ in case that the whole project is further subsidized with funds supporting environmental policy making and regional development; the thick line in the upper diagram is the locus of $C_{min}$ points, when subsidization changes.

are located at easily accessed sites near populated coasts where facilities (with proper equipment and technical staff) are available; the additional FOBs will inevitably be established at remote/distant locations, where such facilities are not expected to be nearby, while the Law of Diminishing (differential or marginal) Returns (LDR) will gradually decrease the network performance, mainly due to data heterogeneity and system entropy increase, all these included/processed within a dedicated internal Knowledge Base (KB).

The latter partial variable, $C_2$, depends mainly on each additional FOB purchase / installation expenses, actually decreasing as a result of 'scale economies', forming (together with the expenses for creating the information processing center and the network infrastructure) the capital cost through depreciation); this dependent variable is a decreasing function of N with increasing algebraic or decreasing absolute rate (i.e. $dC_2 / dN < 0$, $d^2C_2 / dN^2 > 0$ or $d|d\ C_2 / dN| / dN < 0$), because of the LDR validity, especially in the region of higher N-values. Evidently, $N_{opt}$ is the abscissa of the $B_{max}$-point, where the marginal costs $MC_1 = dC_1/dN$ and $MC_2 = |dC_2/dN|$ are equal to each other.

In case of introducing into the network a new large floating platform, properly equipped for FOBs installation / inspection / maintenance / replacement and measurement devices calibration, but not entailing excessive cost, the $C_1$ curve will move downwards to $C'_1$, becoming more flat, since higher cost saving is expected take place in the region of higher N-values; as a result, $N_{opt}$ is shifting to $N'_{opt}$, where $N'_{opt} > N_{opt}$, as shown in Fig. 1a.

In case that the whole project is further subsidized with funds supporting environmental policy making and regional development within an international framework programme, the $C_2$-curve will move downwards to $C'_2$ becoming steeper, since further capital cost decrease will take place in the region of higher N-values, where the economic margins are broader; as a result, $N_{opt}$ is shifting to $N''_{opt}$, as shown in Fig. 1b.

As a matter of fact, both vectors, $(N'_{opt} - N_{opt})$ and $(N''_{opt} - N_{opt})$ have the same direction, indicating shifting of optimal solution to higher N-values, while the final optimal value due to superposition depends on the form of the partial cost functions and their estimated parameter values. On the other hand, the trade-off equilibrium total cost is further minimized in both cases, indicating improvement in economic terms.

Although the conceptual optimization method presented above is correct, it exhibits certain difficulties when applied in practice, because of its rather static character, since it does not take into account (i) other criteria of optimization, which may change in the time cause, and (ii) the transition path for going from macro/regional to micro/positional level, (i.e. for selecting application region and subsequently localizing the exact position of FOBs, through multicriteria analysis).

## 2 Methodology

For overcoming the difficulties mentioned above, we have developed an algorithmic procedure including the following 28 activity stages and 6 decision nodes (for their interconnection see Fig. 2).

1. Detailed determination/limitation of the marine area (MA) under consideration.
2. Collection of data concerning wind speed, height of waves, accidents probability, coastline vulnerability (including seawater quality, ecosystems and anthropogenic environment sensitivity).
3. Risk analysis based on accidents/incidents as related to the data.
4. Environmental/economic impact assessment.
5. Registration /mapping of positions where monitoring / measuring stations are already in operation.
6. Selection of criteria for inadequately monitored regions ranking according to descending order of significance/importance ($1^{st}$ phase).
7. Weights assignment to the criteria vector.
8. Grades assignment to the multicriteria matrix by experts hired ad hoc.
9. Multicriteria ranking of regions
10. Sensitivity /robustness analysis of the preference matrix solution.
11. Re-evaluation of the preference matrix.
12. Costing and determination of the number of the FOBs that might be purchased/equipped/ installed under the constraint of the initial budget.
13. Estimation of the respective subsidy on the basis of (i) the required additional capital for this environmental investment, and (ii) the relevant legislation.
14. Selection of positioning criteria ($2^{nd}$ phase).
15. Weights assignment to the criteria vector by the experts hired for the realization of FOBs positioning.
16. Preliminary positioning of FOBs.
17. Experimental design for supplementary measurements and additional observations.
18. Performance of these supplementary/additional measurements/observations.
19. Assignment of grades to the elements of the preference matrix by the same experts.
20. Multicriteria ranking of the positioning sites.
21. Solution of the location-allocation problem, obtained as a result of performing stage 20, by truncating the ranked output.
22. Re-location of the nodes forming the total output after performing stage 20.
23. Simulation of accidental pollution caused by a tanker transporting crude oil.
24. Search for the cause by means of fault tree synthesis/analysis (FTS/FTA) in a fuzzy version to count for uncertainty within the off-shore environment.
25. Corrective action and checking by running the same simulation routine.
26. Repetition of stage 24 within the on-shore environment, putting emphasis on inventories optimization when anti-pollution materials/means lack their efficiency due to deterioration as a function of time.
27. Repetition of stage 25 within the on-shore conditions, aiming the on-shore conditions, aiming at improvement of the sub-optimality condition.
28. Creation and continuous enrichment of a dedicated internal KB connected with an ontological Intelligent Agent (see [5]) searching within external KB and extracting knowledge from practical experience.

A. Is it sensitive?
B. Is the sensitivity expected to be higher (due to the stochastic nature of data) when the system will be in operation?
C. Are the data adequate for pairwise comparison?
D. Are the nodes (remaining after truncation) adequate to form a reliable network?
E. Are the results satisfactory in relation with oil spill response based on the early warning and the oil slick fate from the point of hydrocarbon release to damaged shoreline?
F. Are the results satisfactory, as regards the ‘just in time’ (JIT) discipline?

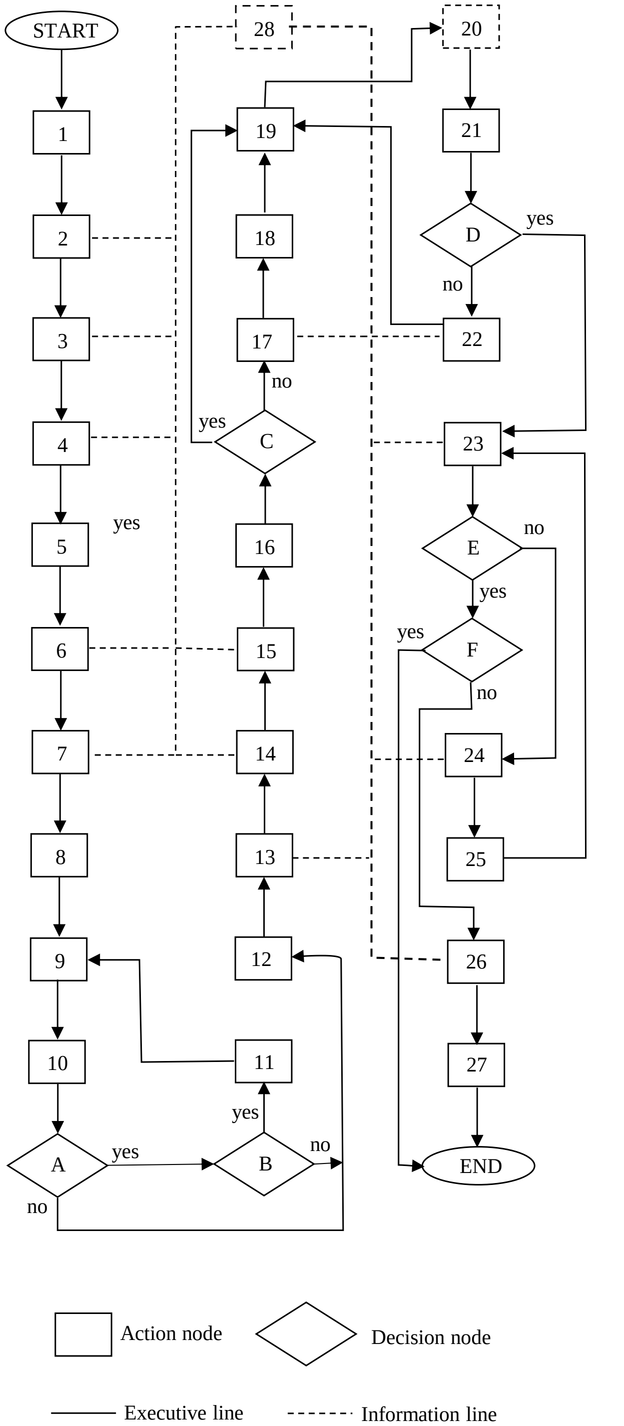


**Fig. 2.** Flowchart depicting the algorithmic procedure presented in the Methodology section herein.

The main criteria selected for the regional and positioning ranking approach (RRA and PRA, respectively), according to stages 6-9 and 14-20, are: average wind speed and height of waves at regional level, C1 and C2, respectively; coastline vulnerability, C3; accidents probability, C4; traffic density and number of ports/facilities at local level, C5 and C6, respectively.

# 3 Implementation

The multiobjective/multicriteria method we used for implementing the methodology presented in the previous Section is the Analytic Hierarchy Process (AHP), because it is simple, widely accepted/used (thus creating a continually enriched KB), and versatile/flexible, as it is proved by its capability to extend/modify/cooperate with other information technology and decision making tools. A representative set of relevant examples is the following: Kuo used it within an international logistics context to suggest a hybrid method for locating a distribution center [6]. Ghuerrero-Baena *et al* incorporated it (actually, its network version – ANP) into an environmental management system to investigate the role of non-financial (intellectual capital) value creation in for-profit-firms [7]. Ozgen and Gulsun combined it with possibilistic linear programming for solving the multi-objective capacitated multi-facility location problem [8]. Janani and Kumar used it for evaluating the technical barriers of large scale sustainable wireless sensor networks [9]. Sultana and Kumar [10], Sanchez-Lorano [11], Vachiduia *et al* [12], and Dragicavic *et al* [13] combined it with a GIS for (i) optimal siting bioenergy facilities, (ii) evaluation of solar farms locations, (iii) hospital site selections, and, (iv) multicriteria with multiscale analysis to characterize urban landslide susceptibility in data-scarce environments, respectively. Konidari and Mavrakis [14] combined it with a multiattribute ranking technique to select instruments for climate change mitigation. Yuksel and Dagdeviren [15] used its network version (ANP) in a SWOT analysis. Shafiee [16] used its fuzzy/network version based on Chang's extent analysis [17], in order to select the "most appropriate risk mitigation strategy" offshore wind farms.

The AHP used herein is in its original form, according to [18,19], since the corresponding fuzzy version may exhibit some difficulties in estimating priorities for pairwise comparison [20]. Nevertheless, fuzzy numbers can be used for extracting information from the experts, provided that defuzzification takes place before processing the results of the relevant questionnaires, so that the final input is expressed in crisp numbers; otherwise, mean values are used weighted with the corresponding standard deviations to count for uncertainty.

In the 1st phase (RRA), the criteria C1, C2, C3, C4 are used. The first of them, concerning wind speed in Greek Seas, is based on four classes of grading scale: ≤ 2.00 m/s, 2.01 – 4.00 m/s, 4.01 – 6.00 m/s, > 6.00 m/s. The second criterion, concerning average waves height, is based on the following classes ≤ 0.62 m, 0.63 – 1.25 m, 1.26 – 1.87 m, 1.88 – 2.5 m, these ranges formed according to statistical data provided by the Hellenic Center for Marine Research (HCMR). The third criterion, concerning coastline vulnerability, is based on the following classes: 0.00 – 1.25, 1.26 – 2.50, 2.51 – 3.75, 3.76 – 5.00, expressed as dimensionless index, the higher value indicating maximum vulnerability. For the fourth criterion, the ESRI Arc Map was used to estimate probability function through the Kernal Density Tool; the classes, following the equidistant pattern are 0.00 – 1.25, 1.26 – 2.50, 2.51 – 3.75, 3.76 – 5.00. The same grading scale is valid for the classes of the criteria C5 and C6, used together with C3 and C4 in the 2nd phase (PRA) of the project.

The following 15 MAs (out of 23 initially collected) were used for the 1st phase AHP, covering the most representative regions in the Greek Seas: Thessaloniki gulf (MA1, FOB1), Amvrakikos Gulf (MA2, FOB2), Gulf of Patras (MA3, FOB3), Euboean Gulf (MA4, FOB 4), Kea – Tzia Sea (MA8, FOB8), Elafonissos Sea (MA10, FOB10), Heraklion Gulf of Crete (MA11, FOB11), Dodecanese – West of Rhodes (MA13, FOB13), Chios – Psara Sea (MA14, FOB14), Dardanelles Exit (MA16, FOB16), East of Rafina (MA17, FOB17), South of Corfu (MA18, FOB18), South of Alexandroupolis (MA19, FOB19), Pagasetic Gulf (MA20, FOB20), South of Crete (MA23, FOB23).

These MAs are considered without taking into account any other media performing inspection/ monitoring through satellite services based remote sensing (especially in following the fate of an oil spill) or FOBs already in operation, like the ones constituting the Poseidon System (HCMR, for details see [21], which has only 10 FOBs: 7 of the ‘Seawatch’ type and 3 of the ‘Seawatch-Wavescan’ (one of them equipped with seawatch deep sea module).

The Weighting Factors and the scores resulted for each criterion are calculated using the AHP method (see Table 1).

**Table 1**: Weighting Factors of the decision criteria.

| RRA Decision Criteria | Weighting Factors |
|---|---|
| C1 | 0,44 |
| C2 | 0,30 |
| C3 | 0,16 |
| C4 | 0,10 |

As an example, the scoring based on the gradual scale for C1 criterion is shown in the intermediate Table 2 below where the numbers in the last column are obtained after normalization, with the highest range values to take 5.00/5.00 grade (corresponding t max wind speed 6 m/s, according to HCMR) and the lowest range values to take 0.68/5.00 grade:

**Table 2**: Scoring of annual average wind speed.

| Gradual Scale of Annual Average Wind Speed | Vulnerability | Scoring |
|---|---|---|
| > 6,00 m/s | Very High | 5,00 |
| 4,01 – 6,00 m/s | High | 2,58 |
| 2,01 – 4,00 m/s | Moderate | 1,36 |
| ≤ 2,00 m/s | Low | 0,68 |

By the total score of the RRA, the first five (5) MAs are in order of decreasing priority: the west MA of the Dodecanese – West of Rhodes (MA13, FOB13), the sea between Chios - Psara (MA14, FOB14), the Dardanelles Exit sea and east of Lemnos (MA 16, FOB16), Heraklion Gulf of Crete (MA11, FOB11), and the MA south of Crete (MA23, FOB23). The final RRA score Table for the two first MAs (13 and 14) is shown below:

**Table 3**: Final score table of RRA.

| | | Scoring | | Final Scoring | |
|---|---|---|---|---|---|
| RRA Criteria | WF | MA 13 | MA 14 | MA 13 | MA 14 |
| C1 | 0,44 | 5,00 | 5,00 | 2,20 | 2,20 |
| C2 | 0,30 | 5,00 | 5,00 | 1,50 | 1,50 |
| C3 | 0,16 | 4,38 | 3,90 | 0,70 | 0,62 |
| C4 | 0,10 | 4,40 | 3,95 | 0,44 | 0,40 |
| SUM | | | | **4,84** | **4,72** |

In the 2nd phase (PRA), the optimal installation locations of the FOBs are selected for the first two marine regions that came up from the RRA phase; the Marine Area west of Dodecanese – West of Rhodes (MA 13) and the Marine Area between Chios - Psara (MA 14).

For the first MA the selected alternative locations for FOBs are FOB13a, FOB13b, FOB13c, FOB13d and FOB13e (see Fig.4 in the Appendix). For the second MA the selected alternative locations for FOBs are FOB14a, FOB14b, FOB14c, FOB14d and FOB14e (see Fig.5 in the Appendix). The number of FOBs (5 in each MA to guarantee economic expenditure comparability by positioning the same number of FOBs of the same type and capital/operating cost) is predetermined as the result of national budget availability in combination with subsidization coming from EU funds and grants provided by stakeholders and sponsors.

The exact alternative locations of FOBs for both sea areas are quoted in the Tables 4 and 5 below:

**Table 4**: Alternative locations of FOBs for MA13 with their corresponding Geographic Coordinates.

| MA Code | FOBs Code | Coordinates |
|---|---|---|
| MA 13 | FOB13a | 26°53'28,699"E 37°19'37,65"N |
| | FOB13b | 26°28'20,621"E 36°48'28,656"N |
| | FOB13c | 27°32'52,424"E 36°54'19,531"N |
| | FOB13d | 28°7'59,455"E 36°30'27,557"N |
| | FOB13e | 27°25'44,6"E 35°57'5,96"N |

**Table 5**: Alternative locations of FOBs for MA14 with their corresponding Geographic Coordinates.

| MA Code | FOBs Code | Coordinates |
|---|---|---|
| MA 14 | FOB14a | 26°21'34,189"E 38°44'0,643"N |
| | FOB14b | 25°42'10,464"E 38°34'7,591"N |
| | FOB14c | 26°11'3,149"E 38°21'25,489"N |
| | FOB14d | 25°43'25,333"E 38°12'53,377"N |
| | FOB14e | 26°18'0,277"E 38°1'31,811"N |

Similarly, the Weighting Factors and the scores resulted for each criterion are calculated using the AHP method for the 2nd phase (see Table 6).

**Table 6**: Weighting Factors of the decision criteria.

| PRA Decision Criteria | Weighting Factors |
|---|---|
| C5 | 0,22 |
| C4 | 0,41 |
| C6 | 0,11 |
| C3 | 0,27 |

The final PRA score Tables, indicating suggested positions for the ranked first and second FOBs for both MAs are presented below:

**Table 7**: PRA final results for MA13.

| | | Scoring | | Final Scoring | |
|---|---|---|---|---|---|
| **PRA Criteria** | **WF** | **FOB 13c** | **FOB 13d** | **FOB 13c** | **FOB 13d** |
| C5 | 0,22 | 4,30 | 4,15 | 0,95 | 0,91 |
| C4 | 0,41 | 3,80 | 4,45 | 1,56 | 1,82 |
| C6 | 0,11 | 4,05 | 4,20 | 0,45 | 0,46 |
| C3 | 0,27 | 4,38 | 4,10 | 1,18 | 1,11 |
| SUM | | | | **4,14** | **4,30** |

**Table 8**: PRA final results for MA14.

| | | Scoring | | Final Scoring | |
|---|---|---|---|---|---|
| **PRA Criteria** | **WF** | **FOB 14b** | **FOB 14c** | **FOB 14b** | **FOB 14c** |
| C5 | 0,22 | 4,35 | 4,15 | 0,96 | 0,91 |
| C4 | 0,41 | 3,45 | 3,65 | 1,41 | 1,50 |
| C6 | 0,11 | 2,80 | 3,95 | 0,31 | 0,43 |
| C3 | 0,27 | 3,79 | 3,86 | 1,02 | 1,04 |
| SUM | | | | **3,70** | **3,89** |

The final results show that the locations where necessary and immediate installation is required are (in order of decreasing priority) the points at FOB13d and FOB14c. Similarly, we can determine FOBs ranking for each MA, after RRA has been performed.

# 4 Discussion

The methodology applied in the present work is oriented towards the development of a local FOBs network by optimizing the location/position of a predetermined number of measuring stations within a properly selected MA. This technique is suitable for creating a standard local network, especially useful as a pilot for extending this methodology to other MAs following the ranking resulted from RRA. On the other hand, our two-phase methodology can be integrated into a unified stage including both, RRA and PRA, at the same time. For performing such an integrated examination, we need a unique independent/explanatory variable, like the fraction $F$ of FOBs within a region, compared with the total numbers of FOBs available at national level. Setting $F=N_R/N_N$, where $N_R$ and $N_N$ are the number of FOBs in the region each time under consideration and the total number of available FOBs at national level, respectively, we can estimate the optimal value $F_{opt}$ by maximizing the total benefit $B(F)_{max} = [B_R(F) + B_N(F)]_{max}$.

The partial benefit $B_R$ is an increasing function of F with a decreasing rate (i.e, $dB_R / dF> 0$, $d^2B_R / dF^2< 0$), because of the Law of Diminishing Returns (LDR), for ‘Returns’ having a marginal or differential form. On the other hand, $B_N$ is a decreasing function of $F$ with a decreasing algebraic or an increasing absolute rate (i.e., $dB_N / dF< 0$, $d^2B_N / dF^2< 0$ or $d|dB_N / dF| > 0$), since the LDR is also valid from a national point of view. Obviously, the point $[F_{opt}, B_{max}]$ is the result of an equilibrium in the tradeoff between $F_R$ and $F_N$, representing opposite forces, depended on the same independent/explanatory variable.

In the time course, the $B_R$ and $B_N$ curves move upwards, becoming more flat, as the result of the

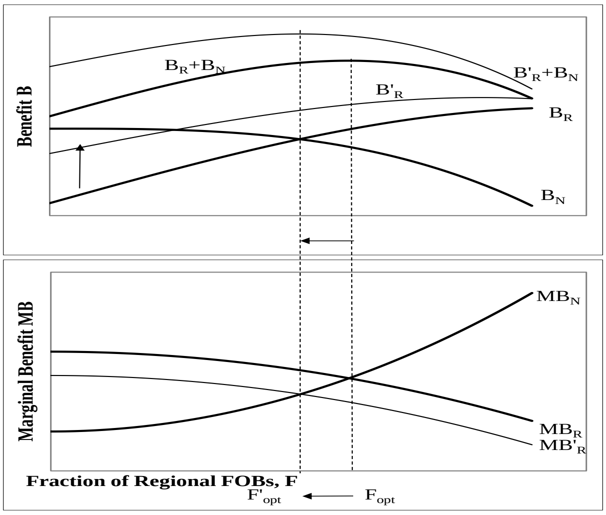


**Fig. 3a.** Dependence of the regional benefit $B_R$ on the explanatory variable $F = N_R / N_N$ and shifting of $F_{opt}$ to $F'_{opt}$ ($< F_{opt}$), when the $B_R$ is changing to $B'_R$ in the time course, as a result of the $K_B$ enrichment in quantitative and qualitative terms.

acquired experience and the stored / processed data (tacit / implicit and expressed/explicit knowledge, respectively); the corresponding consequent shifting of $F_{opt}$ to $F'_{opt}$ and $F''_{opt}$ is shown in Fig.3a and Fig.3b, respectively. The final position of $F_{opt}$ in relation with its original value cannot be forecasted, since the vectors ($F'_{opt} – F_{opt}$) and ($F''_{opt} – F_{opt}$) have opposite direction, while the form of their partial functions is expected to change over time. Nevertheless the $B_{max}$ value will certainly increase although the slope of the curve representing the locus of the $B_{max}$ – points is expected to decrease in the long run (due to impact of the LDR on optimality).

For converting the two-phase approach into an integrated one-phase approach, we can perform the AHP within a **For…Next** loop using as a 'counter' a variable that increases in value during each successive repetition of the loop, according to the following syntax of Visual Basic for applications (VBA) or its corresponding equivalent in another upper/advanced level software language.

**For** counter [as datatype] = start **To** end [step declaration]

Statement expression to be executed for each value of the counter

**Next** [counter value]

The optional step can be positive or negative depending on the starting point within the rank MAs list set *a priori*. Obviously, if the step is omitted it is taken to be the positive unity, while if the counter is not declared outside the loop. We can introduce the **As** clause to declare it as part of the **For** statement.

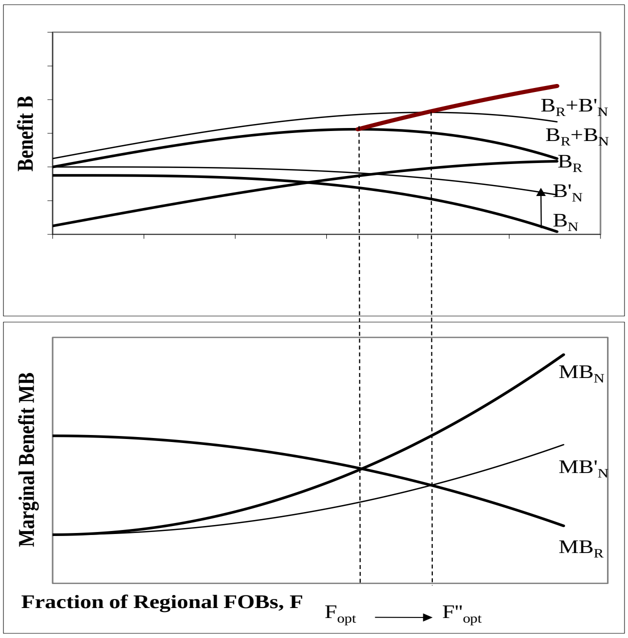


**Fig. 3b.** Dependence of the national benefit $B_N$ on the explanatory variable $F = N_R / N_N$ and shifting of $F_{opt}$ to $F''_{opt}$ ($> F_{opt}$), when the $B_N$ is changing to $B'_N$ in the time course; the thickline is the locus of the $B_{max}$ points in the same time period.

After all iterations (equal to the number of MAs=15 as quoted in the Implementation section) have been performed/finished we may select the *optimum optimorum* or global optimum.

Last, as regards the independence of the criteria used, it is worthwhile noting that the height of waves (C2), depends on wind speed (C1), the length of time the wind blows (duration) and the distance over which the wind blows (fetch). The greater the wind speed and the fetch as well as the longer the duration, the higher the waves. E.g., one-directional wind speed of 75 km/h with 40 hrs duration and 1300 km fetch produce an average wave height 8.5 m with average 135 m wave length and corresponding period of 11 sec with a speed of 39 ft/sec, approximately. Consequently, the dependence of C2 on C1, as well as the dependence of C4 on C5 and C6, create a strong argument for transforming AHP into ANP, if a more exact solution of the multiobjective/multicriteria problem is required.

## 5 Conclusions

The two-phase multiobjective/multicriteria AHP, we have developed, has been proved suitable for selecting/ranking marine areas (MAs) according to sea conditions, coastline vulnerability, and accident probability criteria. The same methodology was proved adequate/satisfactory for FOBs positioning within each MA. This two-phase AHP is successfully embedded in an algorithmic procedure including 28 activity stages and 6 decision nodes aiming at solving the relevant dynamic location/allocation problem under a limited budget, set *a priori* as a constraint. This methodology can be extended in the spatiotemporal domain, indicating priorities for creating a national FOBs network in the medium/long run, since subsidization changes over time, as a result of the different economic combinations/mixtures followed by Greek and EU authorities (Aegean Sea forming EU frontiers to the East and a critical root for hydrocarbons transporting tankers following the North-South corridor, up to splitting into the main sub-corridors leading to Suez and Gibraltar). The algorithmic procedure may also operate inversely as an aid for on-shore facilities, putting special emphasis on inventories optimization when anti-pollution materials/means lack their efficiency due to deterioration as a function of time.

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# Appendix


**Fig. 4.** Alternative positions examined for MA13 (the west MA of the Dodecanese – West of Rhodes (MA13, FOB13)), after performing the 2nd phase of HAP; the ranked 1st and 2nd alternatives are the 13d and 13c, respectively, according to priority shown in Table 7.


**Fig. 5.** Alternative positions examined for MA14 (the sea between Chios - Psara), after performing the 2nd phase of HAP; the ranked first and second alternatives are the 14c and 14b, respectively, according to priority shown in Table 8.