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AN EVALUATION OF MARINE GEOSPATIAL DATA INFRASTRUCTURE (MGDI) BY DELPHI-ANALYTIC HIERARCHY PROCESS (AHP) APPROACH

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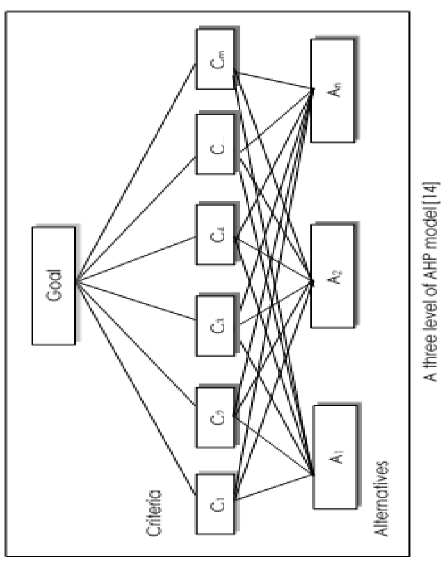
Graphical abstract



Abstract

Decision makings in the contexts of Spatial Data Infrastructure (SDI) and Marine Geospatial Data Infrastructure (MGDI) are recently gaining attention in SDI literatures. Both initiatives are multi-dynamic and complex in nature, thus exhibiting multi-criteria decision-making (MCDM) problems. Yet, there is dearth of multi-criteria evaluation (MCE) decision making framework. In this paper, major criteria for enhanced decisions about MGDI implementations are evaluated. These criteria sourced from literature, further adjudged through Delphi experts group evaluations till consensus was reached on seven criteria. Thereafter, pilot surveys for criteria weightage and ranking based on Analytic Hierarchy Process (AHP) model were carried out, with respondents from marine stakeholders in Malaysia. Results obtained were assessed and compared with scoring procedure; Data and Information had the highest percentage while Social criterion is the least ranked. The significance of these criteria in enhancing MGDI decision for numerous marine activities among the stakeholders are therefore highlighted through this study.

Keywords: Spatial Data Infrastructure, Marine Geospatial Data Infrastructure decision, Delphi Technique, Analytic Hierarchy Process, Multi-criteria decision-making

1.0 INTRODUCTION

The aquatic environment consists of the oceans, sea bodies, lakes and rivers and their inhabitants [1]; and could be translated into different ocean uses, governance and policies at all levels of ocean administration and management, with abundant marine geoinformation [2], necessitating the drive for sustainable environment [3]. Consequently, management issues from multiple and diverse marine related sources are further buttressed [2], particularly, due to availability and accessibility to huge volume of information [4]. Moreover, huge marine big data are always acquired and maintained; despite there are difficulties involved in the face of modern technology, coupled with cost of hardware and software; availability of data, marine experts and other implementation issues. Hence, the Marine Geospatial Data Infrastructure (MGDI) initiative aims at successful management of all the issues relating to marine environment; some of which are thus far highlighted.

In spite of the number of reported initiatives, there exists dearth of research on decision supports systems for either SDI or MDGI via multi-criteria consideration. In addition, there are observed inadequacies in reported cases of some of these initiatives [5-7]. These limitations are basically due to (i) multi-agencies involvement (ii) national ocean policies [6; 8; 9] and ocean governance [5; 10], in a fragmented and uncoordinated fashion [5; 6; 8], with potential conflicts of interest between states and federal and political drive, often complicated with multiplicity of bodies and agencies [7].

These multi-dynamic characterisation concepts thus require analytic evaluation models built on MCDM techniques for elucidation of the various criteria and sub-criteria that influence the marine environment. Among the models for elicitation of expert opinions [11] are Delphi technique, and Analytic Hierarchy Process (AHP) - used for simultaneous handling of multiple-criteria issues as well as incorporating both quantitative and qualitative criteria. According to Tang [11], Delphi is a decision facilitation tool which contributes to informed decision-making rather than being a decision-making tool. On the other hand, AHP simplifies complex decision-making problems by decomposing them into hierarchies in order to determine the relative preferences of decision alternatives through which both quantitative and qualitative criteria are incorporated [12-14].

Thus, the objective of this paper is to review, structure, and evaluate the criteria for MGDI developments. The remaining parts of this paper are therefore presented in the following sections. The next sections describe the status of MGDI; and the analytic technique of MCDM; followed by the research methodology, including the Delphi and AHP procedures. Thereafter, the survey results and discussion are presented after which conclusion was drawn.

2.0 RECENT STATUS OF MARINE GEOSPATIAL DATA INFRASTRUCTURE (MGDI)

The SDI represents the main information clearing house for geospatial issues, while MGDI is also an initiative that is a subset of the SDI [15-19]. Vaez [20] offered definitions of MGDI/Coastal SDI/Marine Cadastre for Canada, Europe, Australia, USA and the Asia Pacific regions, revealing the generally acceptable definitions of MGDI.

Moreover, availability and accessibility to geospatial data, particularly, with respect to decision-making that enhances provisions of products and services are parts of the underlying motivations for SDI [21; 22]. Consequently, 'MGDI decision' (as in Purchasing decision [23]) is introduced in this study to improve the decision support processes of varied marine and maritime activities having geospatial heterogeneous distributions. It is a new concept aligned with MGDI initiative and development based on the understanding that there exists a multi-conceptual nature of stakeholders characterized by different worldviews in terms of marine environment needs, hydrographical services, marine survey services, and various applications that are being explored. Thus, MGDI decision aims at integrating the existing MGDI initiatives with Geospatial Decision Support (GDS) and Geographic Information System (GIS) to improve the decision support processes of varied marine and maritime activities, whose distributions are spatially heterogeneous.

3.0 THE ANALYTIC TECHNIQUE OF MCDM

A multi-criteria decision-analysis (MCDA) problem, according to Saaty [24], is an effective method of handling complex decision-making by clarifying the advantages and disadvantages of the available options under conditions of uncertainty. The AHP was proposed by Saaty in (1980) as a simple, flexible and quantitative method that can resolve difficulties involved in complex, conflicting decision domains by selecting among alternatives that are arranged in hierarchies based on their relative performance with respect to one or more criteria of interest [25]. Thus, in most analytic technique of MCDA, weights are used in elucidating experts' opinions and judgments. This approach is premised on generally accepted scientific knowledge [26; 27].

In order to simplify and deal with complexities, MCDA involves consideration and structuring of a set of factors or criteria which are of relevance based on the identified objectives of the stakeholders. This is implemented through a simple hierarchy structure, consisting of the goal, main criteria, sub-criteria at different levels and sets of alternatives [2; 25] as illustrated in Figure 1, wherein the goal, criteria and the alternatives can be assessed with respect to bottom-level criteria (those on the right of the tree below) and progressively aggregated to reflect preferences at the immediate levels and overall, with their respective weights or priorities.

Areas of applications of AHP are numerous, some of them are hereby highlighted [12; 28-33]. In Ho [34], AHP model was adopted to semiconductor foundry industry; while Yurdakul [30] used it for manufacturing strategy for better output. On the other hand, Liu [31] evaluated the performance of offshore and coastal fisheries policies for sustainable development using AHP. Meanwhile, some of the areas of integration Geographic Information System (GIS) and Multi-criteria Evaluation (MCE), AHP inclusive abounds in literature, while according to Gupta, Mehlawat and Saxena [35] ethical performance (EP) score of asset quality were measured using AHP; and in agricultural farming.

Despite these comprehensive areas of applications of AHP, in terms of MGDI and MGDI Decisions, there exists the dearth of both AHP and/or ANP applications to MGDI development except in port, shipping and transportation management [36], thus necessitating the quest for the assessment of MGDIs by AHP and ANP. The AHP model is based on a fundamental measurement of nine-point scale for pairwise comparisons of two numbers w_i and w_j, that reveals their properties whereby verbal judgments are expressed by a degree of preference or dominance and in particular when the criterion of the comparisons is an intangible one is shown in Table 1. In interpreting the significance of the judgment using ratios (w_i / w_j) of these numbers, a single value from the fundamental 1 – 9 scale of absolute numbers is use instead to depict the ratio $(w_i / w_j)/1$.

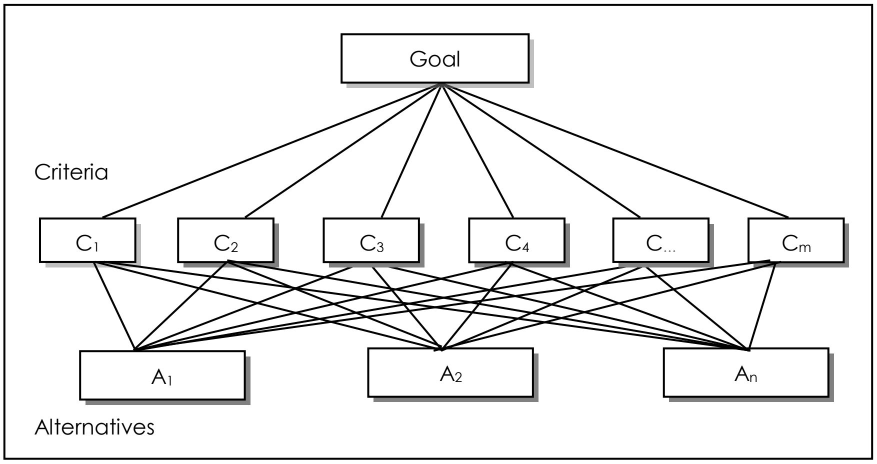


Figure 1 A three level hierarchy in detail [14]

Table 1 Fundamental Scale of Absolute Numbers (Saaty, 2005)

Intensity of Importance	**Definition**	**Explanation**
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

Table 2 RI (n) values [14]

n	**3**	**4**	**5**	**6**	**7**	**8**	**9**
R.I.	0.5799	0.8921	1.1159	1.2358	1.3322	1.3952	1.4537
n	10	11	12	13	14	15	-
R.I.	1.4882	1.5117	1.5356	1.5571	1.5714	1.5831	

It represents the nearest integer approximation to the ratio w_i / w_j [25].The pairwise comparisons are made in expressing the judgments of the experts in form of decision matrices (DM). If $A = \lfloor a_{ij} \rfloor$ be an n-by-n positive reciprocal matrix, so all $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$ for all $i, j = 1, \ldots.., n$. Thus, the principal eigenvalue of A is λ_{max} and is used in the computation of the consistency index; usually, A has $\lambda_{max} \geq n$, with equality if and only if A is consistent; it also represents the biggest eigenvalue for the pairwise comparison matrix. Random Index (RI) represents the consistency index of a randomly generated reciprocal matrix. The average values for matrices of orders 1- 15 generated as in Table 2 and for a sample size of up to 100 [37].

Table 3 Criteria reviewed from literatures

S/N	Critera	Source
1	Economic	EU Lisbon Agenda strategies [38] (Economic and social considerations); Connor, Mckenna and Cooper [39]; LOSC [40]; Balaguer *et al*. [41]; UNEP/IEG/IGSP/2/3 [42]; Rajabifard, Feeney and Williamson [43]; Binns [44]; Binns, *et al*. [45]; UNSD [46]; UN [47]; MMO and Scotland [48]; Binns [49]; Rajabifard [50]
2	Social	EU Lisbon Agenda strategies [38] (Economic and social considerations); Connor, Mckenna and Cooper [39]; LOSC [40]; Arsana, Yuniar and Sumaryo [51]; Balaguer *et al*. [41]; Holland and Borrero [52]; Lance *et al*. 2006; Rajabifard, Feeney and Williamson [43]; UNSD [46]; UN [47]; MMO and Scotland [48]; Binns [49]; Rajabifard [50]
3	Environmental	Adopted through the Gothenburg Agenda [3] (Environmnetal and Environmental Risks); Connor, Mckenna and Cooper [39]; LOSC [40]; Arsana, Yuniar and Sumaryo [51]; Balaguer, *et al*. [41]; Rajabifard, Feeney and Williamson [43]; UNEP/IEG/IGSP/2/3 [42]; Agenda 21; UNSD [46]; UN [47]; Masser [53]; Binns [49]; Rajabifard [50]
4	Sustainable use and conservation of marine resources	National Ocean Policy; Provision of marine spatial data to facilitate decision-making, conflict resolution and sustainable development, Strain, Rajabifard and Williamson [54; 55]; Masser, Holland and Borrero [56]; Holland and Borrero [52]; Sa-nguanduan and Nititvaltananon, [57]; UN [47]; Cooper, Pepper and Osborne [58]; UNDESA [59];
5	Innovation	Rajabifard [60]; Rajabifard [43]; Hamid-Mosaku and Mahmud [62]; Hamid-Mosaku [2]
6	Technology	UNEP/IEG/IGSP/2/3 [42]; Rajabifard, Feeney and Williamson [43]; International (IHO) Standards; Data must be accessible, documented, structured and reliable [52]; sharable [56]; Rajabifard [50]
7	Externalities	Sa-nguanduan and Nititvaltananon, [57]; UNEP/IEG/IGSP/2/3 [42]; Agenda 21, chapter 19: Safer use of Toxic Chemicals; Agenda 21, chapter 17: Protecting and Managing the oceans; Masser, Holland and Borrero [56];
8	Stakeholders	Sa-nguanduan and Nititvaltananon, [57];
9	Good governance	Rajabifard, Feeney and Williamson [43]; Cho [5]; Ng'ang'a *et al*. [10; 63]; O'Hagan and Ballinger [64];
10	Data and Standards	International Hydrographic Organisations Standards [65-67] MS1759 [68]; OGP [69]; MyNODC [70]

4.0 METHODOLOGY

The principles of strategic evaluation and Delphi method [71] were used in arriving at optimal consensus criteria and later incorporated in evaluating the main criteria for MGDI, and MGDI decision. Outcome of extensive literature review revealed the criteria shown in Table 3, which subsequently went through three rounds of Delphi method till consensus was reached; the final seven (7) elucidated criteria (Table 4) are: Economic, Social, Environmental, Resources and Management, Data and Information, Technology, and People. The ranking of these criteria were then achieved through AHP models.

Furthermore, pilot surveys were conducted among three sets of respondents experts' groups, that are tagged as Expert 1 (academic scholars), Expert 2 (mapping agencies), and Expert 3 (producers and end users) respectively from marine stakeholders within the marine environment for ocean based maritime activities.

Table 4 Seven main criteria for MGDI developments

S/N	Final Criteria
i.	Economic
ii.	Social
iii.	Environmental
iv.	Resources and Management
v.	Data and Information
vi.	Technology
vii.	People

4.1 Study Area

The study area is the Malaysian maritime area, being separated by 400 miles by the South China Sea between the peninsular and the states of Sabah and Sarawak. It is bordered by the following countries: Thailand to the north, Singapore to the south; Sabah and Sarawak are bordered by Indonesia while Sarawak also shares a border with Brunei Darussalam (Figure 2).

The country has a total land area of 329, 847 square kilometers [6]. Other geographic features of

Malaysia are shown in Table 5. Based on the 2010 census , the population is 28.3 million [72], while the Gross domestic product (GDP) per capital is $11,513.093 (IMF, 2012).

Table 5 Malaysia maritime areas, number of islands, geographic entity and population [73]

Land Area	329,000 km²
Marine Areas	574,400 km²
Number of Islands	827
Number of Geographic Entity	273
Population	26 millions

4.2 The Delphi Procedures

The Delphi Technique was developed at the Rand Corporation in the 1950s [11; 74; 75] at Santa Monica, CA by Dalkey and Helmer [76]. It is a flexible and systematic means of obtaining sound and professional opinions and judgment from a pool of knowledgeable persons or experts in the realm of a subject matter; combining qualitative and quantitative criteria [77].

4.3 AHP Procedures

The steps involve in AHP are as follow [78]:

Step 1: From the unstructured problem, decompose the decision problem into a hierarchy with the goal at the top, criteria and sub-criteria at other levels and sub-levels, as well as decision alternatives at the final level (Figure 1).
Step 2: The pairwise comparisons judgment consists of elements of the criteria being expressed in a pairwise comparison matrix (D) of decision attributes, using Eqn. 1, and consists of the elements $\{x_{ij}\}$, with degree of preference of the ith criterion over the jth criterion.

Figure 2 Study Area: Malaysia location with respect to neighboring countries (Source: Google Earth, 2014)

The aim is to set their relative priorities with respect to each of the elements at the next higher level.

$$\text{Comparison matrix}$$

$$D = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3n} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ x_{n1} & x_{n2} & x_{n3} & \cdots & x_{nn} \end{bmatrix} \end{array} \quad (1)$$

Step 3: Obtain the Normalised Comparison matrix (R) from Eqn. 2 through normalization procedure from comparison matrix (D), as expressed by Eqn. 3.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \quad (2)$$

and

$$R = \begin{matrix} & C_1 & C_2 & C_3 & \cdots & C_n \\ C_1 & r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ C_2 & r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ C_3 & r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ \vdots & \vdots & \vdots & \cdots & \cdots & \vdots \\ C_n & r_{n1} & r_{n2} & r_{n3} & \cdots & r_{nn} \end{matrix} \quad \text{Comparison matrix} \quad (3)$$

Step 4 and 5: Calculate an inconsistency index (μ), (or consistency ratio) using Eqn. 4 based on Eqns. 1 to 3 in order to reflect the consistency of the decision maker's judgments during evaluation phase.

$$\mu = \lambda_{max} - n/n - 1 \quad (4)$$

where λmax is the principal eigenvalue of the judgment matrix and n is the order of judgment matrix. The closer the inconsistency index to zero, the greater the consistency. The consistency of the assessments is ensured if the equality $(a_{ij}a_{jk} = a_{ik}, \forall i, j, k)$ holds for all criteria. The relevant index should be lower than 0.10 to accept the AHP results as consistent; if not the survey and the comparison should be repeated.

4.4 Instrumentation and Data Collection

The procedure for the survey used is hereby described.

4.4.1 Instrumentation for Main Criteria Weights

Sequel to the consensus reached after iterations through the Delphi method, the final refinement of the questionnaire was drafted; thus representing stages of the instrumentation used for data collection by adopting both scoring and AHP model with the scale shown in Table 1 from experts. It consists of two sections: section one being a general introduction to the survey, including respondent's bio-data; respondent's years of experience in marine related projects; involvement in MGDI related issues and MGDI projects. In section two, the questions are structured on ranking of the criteria using a 1-9 scale with choice from equally important to extremely important. This scale contains only the odd numbers (1, 3, 5, 7, 9).

The AHP flowchart adopted is shown in Figure 3. Meanwhile, the AHP model was used to assess the group pairwise comparisons from these experts, using a new *'MgdiEureka'* system developed in the course of this research and were compared with those from SuperDecisions software. The group pair-wise comparison matrix for the experts, consisting of seven respondents in each group elucidated in this study is shown in Table 6; obtained by the geometric mean method.

Table 6 Group Delphi-AHP pairwise comparison matrix

Intelligent MGDI Criteria	Economic	Social	Environmental	Resources & Management	Data & Information	Technology	People
Economic	1	3.5569	2.2904	1.0771	0.6409	0.9655	1.5536
Social	0.2811	1	0.5504	0.3017	0.1789	0.2714	0.4371
Environmental	0.4366	1.8169	1	0.63	0.3274	0.4932	0.7937
Resources & Management	0.9284	3.3146	1.5873	1	0.5952	0.8963	1.4425
Data & Info	1.5603	5.5897	3.0544	1.6801	1	1.5081	2.4268
Technology	1.0357	3.6846	2.0276	1.1157	0.6631	1	1.6091
People	0.6437	2.2878	1.2599	0.6932	0.4121	0.6215	1

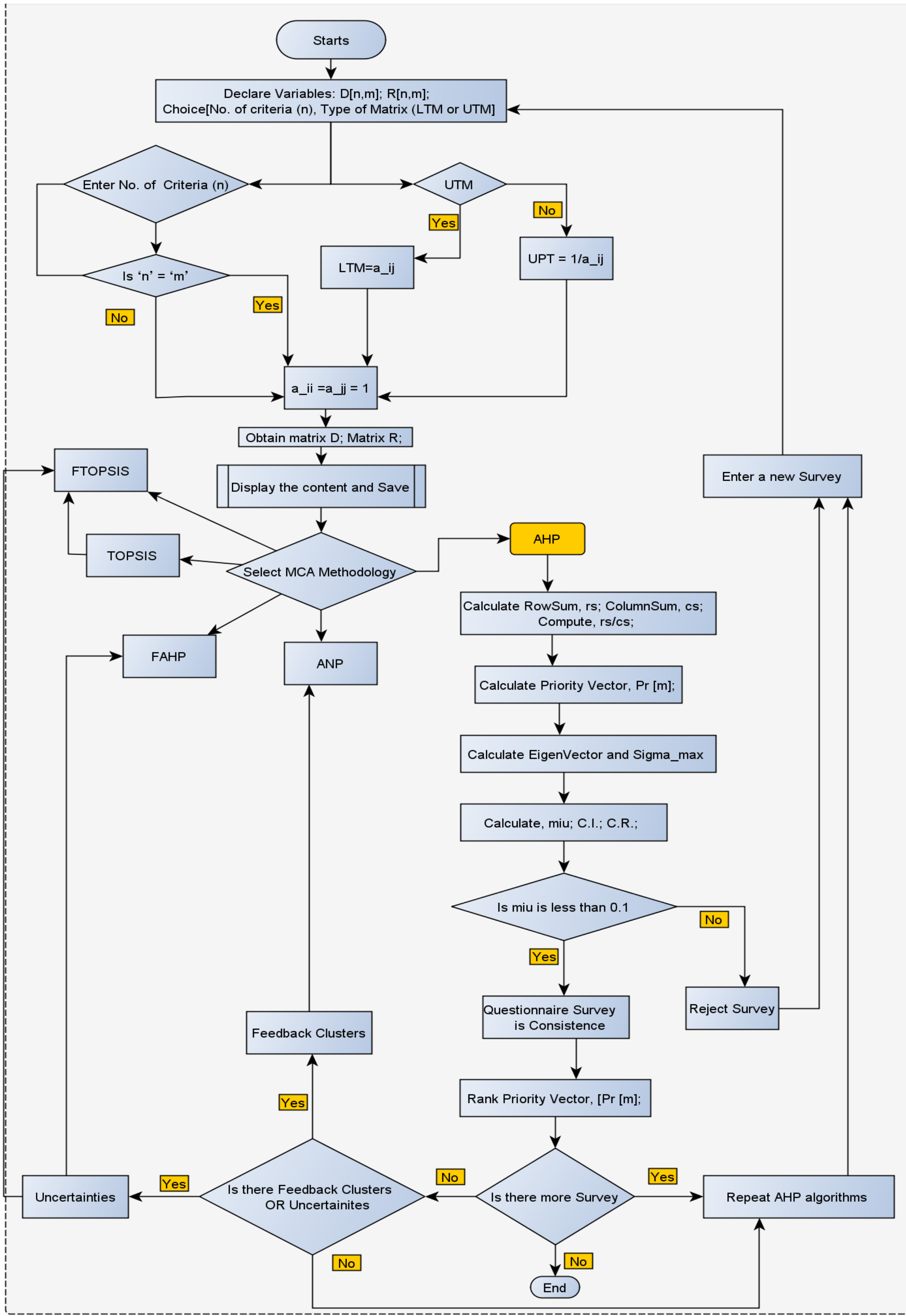


Figure 3 Flow chart for AHP algorithm with respect to some MCE models (Hamid-Mosaku, 2014)

5.0 RESULTS AND DISCUSSION

The results of the scoring and AHP model are presented for evaluation. Also analyses of both the experts and the experts' judgment are discussed.

5.1 Evaluation of Main Criteria by Scoring

The data shows that experts' scores inclusively ranged from 1 to 7; thus, scoring results were computed through Arithmetic Mean (AM) and Geometric Mean (GM). For AM, the results showed mean score values for Data and Information criterion to be 25% of the total; Economic criterion accounted for 17%; Technology accounted for 17%; Resources and Managements accounted for 15%; People for 13%; Environment for 8, while the weight of 5% was elucidated for Social criterion. Here, Economic and Technology had equal scores (17% each), while the least score value of 5% was assigned to Social criterion. Meanwhile, the results from the GM approach showed the following criteria weightings: Data and Information (26%), Economic (17%), Technological (17%), Resources and Management (16%), People (11%), Environment (9%), and Social (5%). Descriptive statistics such as mean, standard deviation and variance for the seven main criteria were also computed. The mean score values are subsequently ranked as shown in Table 7. On the other hand, the standard deviation of each criterion shows the level of their deviation from an average value of (1.043) for instance, with zero value for Data and Information.

Another outstanding aspect of the descriptive statistics is represented by the value of 7 to Data and Information from each of the experts; resulting in the highest average value, and was the highly ranked criterion from the experts. In addition, the descriptive statistics in Table 7 also show the calculated mean scores of each criterion. When plotted against the criteria, it is observed that Data and Information criterion is ranked first for MGDI and MGDI decision as shown in Figure 4. The next important criteria are Technology and Economic; both having the same weight value (4.667) on arithmetic mean and 17% value for the percentage mean score values but with slight changes (0.161) on the geometric mean. Next is the Resources & Management criterion, having a weight value (4.333) on arithmetic mean and (4.160) on the geometric mean; with 15% and 16% values on percentage mean score values respectively. In addition, these four sets of criteria are found within the upper parts of important plane of this figure denoted between value '9' and '4' lines, while the other three criteria are found within the lower plane and are located between '4' and '1'.

Based on the analyses above, it can be deduced that the experts attach more importance to the criteria on the upper part of this figure. This implies that greater emphasis is placed on People criterion whereas less emphasis is placed on environmental, and Social criteria. The case of Environmental criterion at lower part of this plane in this figure is somehow different from the usual consideration in most hydrographic campaigns where environmental concern is paramount. This might be due to some inherent subjectivity of either the expert(s) or the experts' judgment. Furthermore, this result highlights the competitive nature of these criteria as evident from the experts' judgments.

5.2 Evaluation of main criteria by AHP

The result of the Delphi pair-wise comparison decision matrix (DM) used for this study is shown in Tables 7, comprising of the Normalised Decision Matrices, Priorities, and the consistency ratio (CR). Interestingly, the consistency ratio (CR) was less than 0.10 (0.0007) – the accepted CR value for AHP model (Saaty, 1977). Thus, the respective ranking of these criteria is shown in Table 8.

Consequently, the AHP results from the three experts' group shows that Data and Information criterion is the most highly ranked, with a weight of 26.17% of the total; Technology and Economic accounted for over 17% each, though Technology criterion was higher; while Resources and Managements had 15.28%; People 10.78%; Environment 8.6%, while the least ranked weight of 4.7% was elucidated for social criterion (Table 9).

Meanwhile, the comparison with scoring method is shown in Table 10. The same order of ranking was also observed though with slightly different values. Data and Information criterion is still the most highly ranked criterion 25.6% weight; Technology (17.0%), while Economic accounted for 16.7%. Furthermore, while Resources and Managements had 15.5%, People criterion has 11.9%; both having relatively higher values than those from Delphi-AHP; for the remaining criteria, the values from Delphi-AHP were observed to be higher. Meanwhile Environment 8.5%, while the least ranked weight of 4.7% was elucidated for social criterion. The final rankings of these criteria from the different experts are therefore aggregated by geometric mean for both Scoring and Delphi-AHP methods, as shown in Table 10. In all, Data and Information had a weight of 25.9%; Technology (17.2) now higher than Economic (16.9); with Social criterion had the least value of 4.7%. On the other hand, Environment criterion is almost at the end of the ranking, this observation seems unlikely for marine environment. Technological factor and viable economic consideration are seemingly equally ranked due to importance to MGDI for MGDI Decisions by the attendant stakeholders.

Table 7 Delphi-AHP - Normalised Decision Matrix and Priorities results

Intelligent MGDI Criteria	Economic	Social	Environmental	Resources & Management	Data & Info	Technology	People	Priority
Economic	0.1699	0.1674	0.1946	0.1658	0.1679	0.1677	0.1677	**0.1716**
Social	0.0478	0.0471	0.0468	0.0464	0.0469	0.0472	0.0472	**0.047**
Environmental	0.0742	0.0855	0.085	0.097	0.0858	0.0857	0.0857	**0.0855**
Resources & Management	0.1577	0.156	0.1349	0.1539	0.1559	0.1557	0.1557	**0.1528**
Data & Info	0.2651	0.263	0.2595	0.2586	0.2619	0.262	0.262	**0.2617**
Technology	0.176	0.1734	0.1723	0.1717	0.1737	0.1737	0.1737	**0.1735**
People	0.1094	0.1077	0.107	0.1067	0.1079	0.108	0.108	**0.1078**
								CR Test result: 0.0007

Table 8 Sorted Priorities from the Delphi-AHP result

Sorted Criteria-	Sorted Priority	Ranking
Data and Information	0.2617	1
Technology	0.1735	2
Economic	0.1716	3
Resources and Management	0.1528	4
People	0.1078	5
Environmental	0.0855	6
Social	0.0470	7

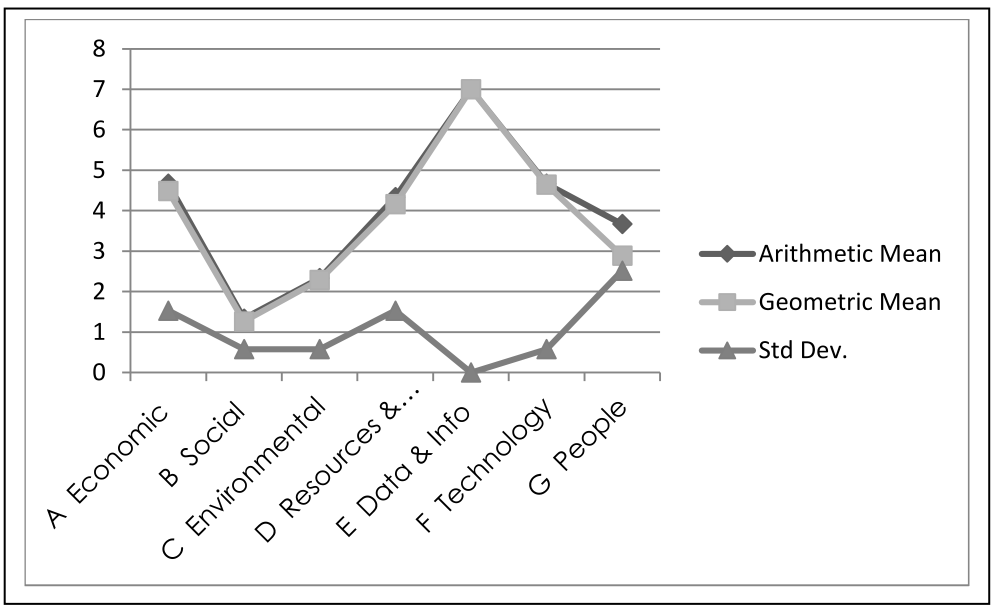


Figure 4 Mean values and Standard Deviation of criteria

Table 9 Results of Ranking by Scoring from different Experts

Intelligent MGDI Criteria	Scores					Mean Score Values		% Mean Score Values			
	Experts Group 1	Expert Group 2	Expert Group 3	Min	Max	Average	Geometric Mean	% Average	% Geometric Mean	Std Dev.	Var
Economic	5	3	6	3	6	4.667	4.481	17	17	1.528	2
Social	2	1	1	1	2	1.333	1.260	5	5	0.577	0
Environmental	3	2	2	2	3	2.333	2.289	8	9	0.577	0
Resources & Management	6	4	3	3	6	4.333	4.160	15	16	1.528	2
Data & Info	7	7	7	7	7	7.000	7.000	25	26	0.000	0
Technology	4	5	5	4	5	4.667	4.642	17	17	0.577	0
People	1	6	4	1	6	3.667	2.884	13	11	2.517	6
					Sum	28	27	100	100		

Table 10 Comparisons of the Rankings of Main Criteria from Scoring and AHP model

Intelligent MGDI Criteria	% Ranking (Geometric mean)		% Ranked values
	Scoring	**Delphi-AHP**	
Data & Information	25.6	26.17	25.9
Technology	17	17.35	17.2
Economic	16.7	17.16	16.9
Resources & Management	15.5	15.28	15.4
People	11.9	10.78	11.3
Environmental	8.5	8.55	8.5
Social	4.7	4.7	4.7

This table also revealed that while the rankings are in the same order, their values are relatively not the same. This implies that the criteria are suited for MGDI and MGDI Decision.

6.0 CONCLUSION

This paper evaluated the criteria for developing and implementing Marine Geospatial Data Infrastructure through extensive literature search within the MGDI domain and other related fields. In the end, seven different criteria were elucidated. Investigations on these criteria were further conducted through experts' opinion in form of a Delphi survey until consensus was reached after several iterations. Pilot surveys through questionnaire evaluations provided empirical results for further justification of the experts' rankings. The priorities data derived from the AHP model were further statistically proven not to be significantly different, suggesting that the experts' opinions are similar. Further analyses were performed on these data to derive the percentage average ranking for the seven main criteria with their respective standard deviation and variance that are suited for MGDI design and developments. Thus, the ranking obtained shows the order of importance of these criteria, as well as the importance to be attached to them by stakeholders. For instance, Technological and Economic considerations are more prioritized than Environment criterion, as the people are also considered to be more important than the Environmental criterion. This seems not to be the usual practice in typical hydrography projects where environmental factors are usually given a higher consideration or preference than what was obtained and revealed in this situation.

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