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Enhancing Spatial Data Accessibility in Ghana: Prioritization of Influencing Factors Using AHP*

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Abstract

The need to improve access to spatial data has attracted both research and policy attention because it is considered as one of the key requirements for sustainable development. Since multiple stakeholders are involved in the spectrum from spatial data production to use, an effort to make spatial data widely accessible requires multi-stakeholder approaches to foster consensus over multiple decision criteria. The objective of this study was to explore and structure a multi-criteria decision-making problem regarding access to spatial data in Ghana from a multi-stakeholder perspective; and to prioritize (rank) spatial data accessibility components and influencing factors for policy decisions. The Analytic Hierarchy Process (AHP) was used as a tool to support the structuring of the multi-criteria decision problem and the multi-stakeholder process. A three-level AHP structure was constructed to examine the spatial data access problem, with a main objective, four sub-objectives and five alternatives. Spatial data accessibility was decomposed into four components (discoverability,

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retrievability, usability and affordability) which were used as sub-objectives (criteria). More so, spatial data access is mediated by influencing factors (institutional, technical, policy/legal, socio-cultural and economic) which were used as alternatives. Fifty individuals from twenty four organizations were interviewed and later engaged in a focus-group discussion to generate weights (priorities) for the accessibility components and the alternatives. The results provide both qualitative and quantitative information to decision makers regarding the spatial data access problem and their priorities from the perspective of enhancing access to spatial data. Regarding accessibility components (objectives), discoverability and retrievability had the highest priorities while technical and institutional issues had the highest priorities with regard to the influencing factors. Considering the overall impact on the main objective and in the face of limited resources, it is concluded that improvement in the technical and institutional environment with the view to improving discoverability and retrievability require the highest priority in order to enhance access to spatial data in Ghana.

Keywords: Analytical Hierarchy Process (AHP), spatial data accessibility, GIS, SDI, multi-criteria decision-making, prioritization problem, Ghana

1. INTRODUCTION

The need to improve access to spatial data has attracted both research and policy attention because it is considered as one of the key requirements for sustainable development. Spatial data normally provides information on the geographic location of objects or phenomena (with or without attributes) on Earth surface. It is now common knowledge that about 80% of information used in decision making at all management levels is spatial; and this underscores the criticality of spatial data in sustainable development. Spatial data is expensive to collect, process and maintain. Therefore, improving access to spatial data has a huge potential in minimizing cost and doubling of effort in data collection, processing and management (Groot, 1997). It also has the potential to facilitate harmonization, standardization and integration of data across jurisdictions and domains (Yawson et al, 2010; Crompvoets et al, 2008). Thus, improved access to spatial data increases the quality of data and decisions, frees time and resources for other purposes and ultimately enables development. Williamson et al (2003) and many references therein explain the manifold benefits offered by improved access to spatial data to the public sector, private sector, government and citizens. Multiple stakeholders are involved in the production and distribution of spatial data and, thus, any meaningful initiative to make spatial data widely and easily accessible requires multi-stakeholder processes to harmonize interests, values and perspectives.

Geographic Information Systems (GIS) are used in managing and analyzing spatial data to unravel complex spatial relationships and interactions among geographic phenomena to address spatial decision problems. Advances in GIS and communication technologies, combined with the rapid growth of information networks, are transforming businesses and markets, scientific analysis of socio-ecological systems and communication of analytical results, as well as revolutionizing decision-making and providing new insights into conception of spatial-temporal dimensions of phenomena. This, in turn, is catalyzing the empowerment of citizens and communities in myriad ways and enabling sustainability (Babalobi, 2003). Specifically, the process of decision-making and the quality of decisions have improved dramatically due to quality information input. Applications of GIS have gained currency at all levels of decision-making as spatial information forms a greater component of the information resources used at all levels of decision-making (Giff et al, 2008; Rhind, 1999). GIS and its allied technologies have become the premier tools for research, policy formulation, decision-making and monitoring of sustainable development (Longley et al, 2001; Strain et al, 2006). Perhaps, apart from its analytical power, the greatest utility of GIS in sustainable development is its ability to enable compatibility in decision-making across multiple jurisdictions and over varying spatio-temporal scales (Mansourian et al, 2006).

GIS subsists on spatial data. Consequently, improved access to existing spatial data is essential to ensuring wider use of GIS analytical products to support decision-making. Spatial data infrastructure (SDI) has been developed at varying scales around the world in response to the need to make spatial data widely accessible (Geudens et al, 2009). As a result, current discourse on access to spatial data is largely situated within the framework of SDI. SDI can be defined as the assemblage of relevant technologies, policies, and institutional arrangements that facilitate the availability of, and access to spatial data (Nebert, 2004). SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, business and industry, the non-profit sector, academia and even by citizens in general Thus, SDI provides a framework for analyzing and manipulating factors that mediate the process of accessing spatial data. The relevance of spatial data and its accessibility can therefore be deduced from the huge corpus of literature on SDI (e.g., Nebert, 2004; Rajabifard et al, 2002; Lacasta et al, 2007; Scholten et al, 2006; Groot, 1997; Tuchyna, 2006; and Crompvoets et al, 2008). Williamson et al (2003) have explained the concepts, structure, components and the development of SDI. Regardless of differences in scope, complexity and functionality, all SDIs are primarily designed to make spatial data accessible to a wider user community.

Unfortunately, developing countries are characterized by low levels of access to spatial data (Yawson et al, 2009; Poku et al, 2007).In Ghana, improvement in access to spatial data is critical to effective and efficient resource and environmental management, governance, policy formulation, and development planning in general Ghana is blessed with various natural resources and is expected to join the oil-producing nations in the last quarter of 2010. The challenges in the nexus of natural resource exploitation and development raise the imperative for increasing the availability and access to spatial data in order to benefit fully from GIS. However, the absence of a functional SDI makes access to spatial data very difficult, expensive and often frustrating (Yawson et al, 2010). Ghana created a framework for sharing spatial data in the 90s. This framework was called the National Framework for Geospatial Information Management (NAFGIM). Unfortunately, NAFGIM could not mature due to resource constraints and erosion of interest on the part of the participating institutions as they had to refocus their resources and attention on their core mandate immediately after the closure of the project which necessitated the creation of NAFGIM (Karikari, 2006; Yawson et al, 2010). According to Yawson et al (2009; 2010), currently, Ghana has no functional SDI. However, as a result of NAFGIM and post-NAFGIM projects (some of which are still ongoing, e.g. the Ghana Land Administration Project), important framework and application datasets exist in digital formats in various institutions but are not easily and widely accessible to the public.

Since SDI provides an influencing milieu that enhances access to spatial data, it is important to examine which SDI influencing factors can be manipulated to increase access to spatial data (in lieu of a complete SDI) and at the same time facilitate the realization of SDI over a reasonable time horizon. More so, in the discourse on spatial data access, there is paucity of information on how and what components of accessibility and influencing factors should be prioritized for step-wise improvement. Considering the fact that Ghana is a developing country with limited resources for creating SDI, it is imperative to prioritize objectives and actions in order to enhance access to spatial data and eventually realize a fully functional SDI in an incremental manner. In the face of finite resources, choice is inevitable. However, in this case, the cumulative and collective improvement of all influencing factors is ultimately required to make spatial data widely accessible. Therefore, prioritization, rather than choice, of the influencing factors for improvement is preferable. This prioritization is a multi-stakeholder decision-making problem with multiple criteria, requiring the application of tools and approaches simultaneously amenable to multi-stakeholder and multi-criteria decision-making. Consequently, Analytic Hierarchy Process (AHP), which is applicable to multi-criteria and multi-stakeholder decision making and prioritization of alternatives, was applied to structure and examine the problem of enhancing spatial data access in Ghana and to prioritize the alternatives for action.

1.1. Conception of Accessibility to Spatial Data

Accessibility has different meanings, components and applications in different domains and contexts. Consequently, it is important to define the scope and qualities of accessibility as applied in this study in order to delimit the boundaries of influencing factors that mediate accessibility. In this paper, access to spatial data is viewed as a process that entails the ability to locate, view, evaluate, retrieve and exploit or use spatial data held by another entity (Williamson et al, 2003). In discussing access, one can focus on procedural matters (instrumental rationality) or the ultimate goal (value rationality). However, the definition indicated in this paper includes both the process and the goal of accessing spatial data. In literature, some authors separate the process into discoverability, access and evaluation (e.g. Lacasta et al, 2007); and thus limit access to retrieval of data from an SDI. Groot (1997) indicates that access to spatial information means the user is allowed to know what information is available and where, what conditions of access and use are, and how much it will cost. Thus, access here consists of discoverability, affordability and conditions for retrieval and use. Consequently, and based on varied definitions and applications of the term in literature, accessibility in this study is decomposed into four main components: discoverability (consisting of locating, viewing and evaluating the data), retrievability (the ease with which the prospective user obtains the data), affordability (cost of data plus other cost of effort or transaction) and usability or exploitability (fitness for user's purpose). Discoverability presupposes the data is available at a particular time and place and that there is a mechanism that enables a prospective user to become aware of the existence of the data and its properties. Retrievability implies a mechanism exists that allows a prospective user to obtain the data by ordering, requesting, downloading or copying, and the data is delivered in appropriately packaged format and/or medium. Affordability means the cost of the data itself and effort of access is amenable to the budget of the user. Usability or exploitability suggests the properties of the data fit the user's purpose for accessing the data. Therefore, these components can serve as indicators for analyzing or improving spatial data accessibility.

1.2 Analytic Hierarchy Process (AHP)

Any effort to make spatial data widely accessible involves multiple stakeholders and decision variables (or criteria). In this study, multiple stakeholders need to agree on the prioritization of influencing factors and accessibility components. The prioritization decision problem can therefore be supported by multi-criteria analysis (MCA) tools, which are decision support tools that allow stakeholders to evaluate alternatives on the basis of clearly defined multiple criteria in order to arrive at a collective decision or choice. Such tools also help stakeholders move from a sphere of varying and often competing interests to one of harmonized interest, collaboration, cooperation and shared vision (Yawson et al, 2009). Geudens et al (2009) and references therein explain the key concepts underlying

MCA and the incorporation of multi-stakeholder perspectives for the evaluation of SDIs and related policy strategies.

While a number of MCA tools exist and could be applicable to this study, the choice of MCA method strongly depends on the problem to be solved, which could be *choice*, *sorting* or *ranking* problem (Geudens et al, 2009) and the particular demands of the method. Multi-attribute Utility Analysis (MAUA) is a powerful tool for multi-criteria, multi-stakeholder decision making. It is a mathematical tool for evaluating and comparing alternatives to enable informed choice among alternatives that have varying degrees of desirable attributes. It is normally applied to a choice problem in which there are usually mutually exclusive alternatives and the choice decision is based on multiple criteria that maps onto the varying degrees of desirable attributes of the alternatives. To achieve this, MAUA uses a utility function to map a multi-dimensional attribute space into a one-dimensional preference space. A detailed treatment of the theory and applications of MAUA can be found in Edwards (1982) and Keeney and Raiffa (1976). Three reasons informed our choice of AHP over MAUA. First, the use MAUA has been limited to the arena of decision science and scarcely in public-policy decisions because it is difficult to construct and requires huge amount of time, money and other resources for its effective implementation (Marttunen and Hamalainen, 1995; Merkhofer et al, 1997). Second, MAUA is better adapted to quantitative studies in which the attributes of alternatives have quantitative values, otherwise scoring and weighting becomes overly subjective to the analyst. Third, MAUA is better for analyzing *choice problems* and less desirable for *ranking* problems. For all these reasons, AHP is a better alternative. AHP is better adapted to qualitative studies, as is the case in this study, and offers a simple and direct expression of scale of preference. In this study, the problem on hand is not one of choice in which only one optimal solution or alternative is desired, but prioritization (ranking) of alternatives in an order of preference and where all alternatives are to be dealt with eventually.

SWOT (strength, weakness, opportunities, threats) analysis is also a tool amenable to multi-criteria and multi-stakeholder decision making. As a framework, it is used to examine the internal and external factors that can lead to the success or otherwise of a project or an initiative. Its ultimate aim is to identify and maximize strengths and seize opportunities while minimizing weaknesses and threats related to a project or an initiative. In this study, SWOT was not chosen because the study is not aimed at identifying ways to take advantage of strengths and exploit opportunities inherent in a proposed SDI initiative or project, while minimizing the impacts of weaknesses and threats. Rather, the goal was to unravel the order in which actions can be taken sequentially on influencing factors, in line with availability of resources and will, towards making spatial data widely and easily accessible. The same can be said of cost-benefit analysis and cost-performance analysis which are useful for assessing the value of a project or an initiative by comparing its costs with its benefits or measures of performance value respectively. Finally, Dominance Analysis (DA) has also emerged as a tool useful in applications in multi-criteria decision-making. In DA, an alternative is said to be dominant in an array of alternatives if it’s scores or attributes are most favourable in all the criteria relative to the other alternatives. That is, it has a favourable mix of attribute scores or qualities that satisfies the rational expectations of the decision-maker. Wong et al (2009) offer a simple example in which a customer looks for a vacation package using three criteria: price, hotel class and number of stops. In this case, a package that is better in one factor (e.g. price) but is not worse than the other packages in any of the other factors is said to be dominant. While DA is amenable to multi-criteria decision-making, it has not been widely applied in multi-stakeholder decision-making applications. It is a multi-criteria decision-making tool generally useful to a single decision-maker or analyst but may be difficult to apply in a multi-stakeholder, multi-criteria decision-making context. As a result of these reasons and in view of limited resources and time, we found AHP more appropriate for this study. The rest of this section deals with a description of AHP.

Developed by Saaty (1980; 1986), the foundation of the AHP is a set of axioms that carefully delimits the scope of a problem environment (Forman and Gass, 2001). The AHP is a multi-criteria decision support and evaluation approach that is used in finding optimal measures on the basis of hierarchical problem structure (Ziolkowska, 2008). It is based on the well-defined mathematical structure of consistent matrices and their associated right eigenvector’s ability to generate true or approximate weights (Saaty, 1990).

The AHP methodology uses a fundamental scale of absolute numbers to compare criteria, or alternatives with respect to a criterion in a pair-wise mode. The fundamental scale (called the AHP standard scale) has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes just as well or better than other scales (Saaty, 1994). It converts individual preferences into ratio scale weights (local priorities) that can be combined into a linear additive weight for each alternative; and the resultant linear additive weight can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice or prioritizing the available options (Forman and Gass, 2001). AHP can be considered to be both a descriptive and prescriptive model of decision making since it is known to reflect the usual multi-criteria decision-making process by individuals. With regard to multi-criteria, multi-stakeholder decision-making process, the utility of AHP lies in its three basic functions (Forman and Gass, 2001): (1) structuring complexity, (2) measuring on a ratio scale, and (3) synthesizing of component parts into whole.

AHP has three axiomatic pillars (Forman and Gass, 2001). The first pillar is the reciprocal axiom, which requires that, if PC(EA,EB) is a paired comparison of elements A and B with respect to their parent, element C, representing how many times more the element A possesses a property than does element B, then PC(EB,EA) = 1/PC(EA,EB). For instance, if A is 3 times larger than B, then B is one third as large as A. The second pillar is the homogeneity axiom which states that the elements being compared should not differ too much, else there is the tendency for larger errors in judgment which decrease accuracy and increase inconsistency. The third axiom relates to hierarchic composition and states that judgments about, or the priorities of, the elements in a hierarchy do not depend on lower level elements. This axiom is related to the independence (or otherwise) of the elements at different levels of the hierarchy. Where preference of a higher level element depend on a lower one (feedback effect), the third axiom does not apply.

The strengths and utility of AHP derive from its applicability to both quantitative and qualitative analysis and its ability to integrate multi-stakeholder views in a multi-criteria decision-making situation. Consequently, AHP has found applications in several domains. According to Steur and Na (2003), Vaidya and Kumar (2006), Saaty and Vargas (1991) and Ho (2008), AHP has been applied in areas such as engineering, finance, government, education, industry, management, medicine and related fields, manufacturing, and sports for the following problems: priority setting, resource allocation, risk assessment, performance measurement, system design and assurance of system stability, optimization, planning and conflict solution. Ziolkowska (2008) applied AHP to examine the cost-effectiveness of agri-environmental measures in Poland within the framework of the European Agricultural Guidance and Guarantee Fund and showed that extensive meadow farming and organic farming represent the highest environmental benefits. AHP and linear goal programming model were integrated to solve a problem of optimal allocation of grain harvest and post-harvest facilities in China (Guo and He, 1999). Malczewski et al (1997) also applied AHP to deliver solution for land use patterns that minimize conflicts and maximize consensus among stakeholders in Mexico. Also, AHP was combined with SWOT (strength, weakness, opportunity and threat) analysis to assess the prospects and challenges for silvopasture adoption in Florida (Shrestha et al, 2004). Similar methods were applied to a forest-certification case (Kurttila et al, 2000) and acceptability of community-based forest management to stakeholders (Masozera et al, 2006). Applying AHP in the analysis of the impact of hidden failures in special protection schemes (SPS) of electrical power system of the Western States Coordinating Council (WSCC) in the United States, Nigim et al (2003) concluded that the application of AHP reduces time and effort in locating the most and least vulnerable SPS. Roper-Lowe and Sharp (1990) also applied AHP to a multi-stakeholder decision concerning the selection of a computer operating system to handle the cargo shipments of British Airways. They concluded, however, that even though AHP eased the multi-criteria and multi-stakeholder decision-making process, there were some difficulties associated with the use of AHP, particularly the lack of explanatory assignment to final weights make interpretation difficult. At the time of writing this paper, only one paper was found which used AHP to assess SDI policy strategies in Flanders, Belgium (Geudens et al 2009) but no paper on the application of AHP in multi-criteria, multi-stakeholder decisions to set priorities for making spatial data accessible.

1.3 Aims and Objectives

The overall aim of the study was to explore the problem of spatial data accessibility in Ghana from a multi-stakeholder perspective and to use a multi-criteria analysis tool to prioritize (rank) alternatives for action towards improved access to spatial data. Specifically, the study has three objectives. First, the study was undertaken to identify key SDI factors that influence access to spatial data in Ghana. The second objective was to explore the interaction between the influencing factors and the components of accessibility (i.e. discoverability, retrievability, affordability and usability) from a multi-stakeholder perspective. Finally, AHP is applied as a tool to structure the problem of spatial data accessibility and to prioritize the accessibility components and influencing factors for improvement.

2. METHODOLOGY

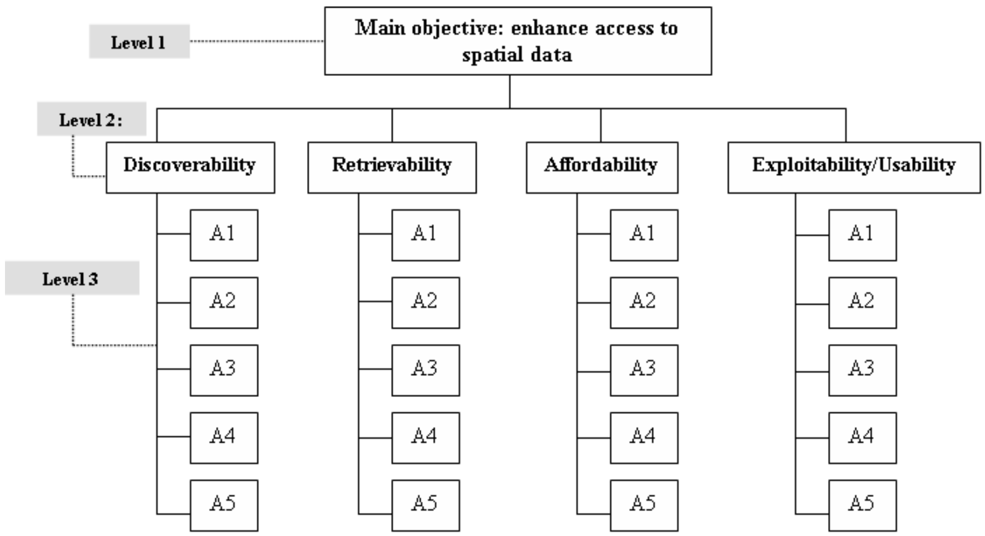
Fifty (50) individuals from twenty four (24) organizations consisting of both public and private spatial data producers and/or users (including research institutions and universities) were selected for the study. The organizations were selected from the Greater Accra, Ashanti and Western Regions of Ghana based on their capacity, mandate or potential to produce and/or use spatial data, while the individual respondents were key informants selected from staff whose work relate to spatial data collection, application or management. Questionnaire and focus-group discussion were used as the major instrument for data generation. The data collection was conducted in two phases. The first phase consisted of face-to-face interviews with respondents between July 2009 and December 2009; and the second phase consisted of focused-group discussion and the creation of pair-wise comparison matrix as required by AHP. The questionnaire had both open- and close-ended questions. Among other things, the questionnaire elicited demographic information, opinion on the ease (or otherwise) with which spatial data is accessed and suggestions to improve spatial data accessibility in Ghana. Essentially, the questionnaire elicited information on what factors affect (enhance or constrain) access to spatial data, how those factors influence the components of accessibility of spatial data and the prioritization required for the improvement of the influencing factors to enhance spatial data access.

2.1 AHP Application

A number of factors mediate to constrain or enhance the process of spatial data access. These factors, termed *influencing factors* in this paper, interact with and influence the components of accessibility. After a preliminary analysis of the responses, the factors identified by respondents as constraining or enhancing access to spatial data were consolidated into five main influencing factors (Nebert, 2004; Williamson et al, 2003): institutional, policy/legal, technical, socio-cultural and economic. Subsequently, the respondents were invited to a forum to discuss and agree on the influencing factors and determine the scores for the objectives and alternatives to allow for the creation of weights and coefficients as required by AHP. The participants were divided into two groups (each group had a mixture of both data users and producers) for a focused-group discussion. AHP is a hierarchy-based technique used for setting priority in a complex, multi-criteria problematic situation (Nigim et al, 2003). A typical hierarchy involves representing the overall objective of the decision at the top level (level 1); the element (criteria) affecting the decision, including hidden criteria, at the intermediate level (level 2), and the decision options (alternatives) at the lower level (level 3) (Ziolkowska, 2008; Nigim et al, 2003). An AHP model was developed for the data access case, having three hierarchical levels as shown in figure 1. Level 1 represents the overall goal (enhancing access to spatial data), Level 2 represents the criteria or objectives (improvement in accessibility components: discoverability, retrievability, affordability and exploitability/usability of spatial data) and Level 3 represents the alternatives (improvement in influencing factors: institutional, technical, policy/legal, socio-cultural and economic). The influencing factors are framework factors that affect the development and operation of SDI, and thus, ultimately influence access to spatial data. The state of each of these factors significantly impacts on the components of accessibility. The AHP procedure is aimed at ranking these alternatives, with respect to the overall judgment of the group (via the criteria)

After the hierarchical structuring of the problem, a prioritization procedure to determine the relative importance of the elements in each level of the hierarchy was followed. Here, elements in each hierarchy were pair-wise compared with respect to their importance to the decision-making. AHP uses a verbal scale (called the AHP Standard Scale – Table 1), which enables experts to incorporate subjectivity, experience and intuition in a natural way (Nigim et al, 2003). Due to the fact that AHP scale uses a ratio scale for human judgments, the alternative weights show the relative importance of the criteria in achieving the goal of the hierarchy.

Figure 1: Hierarchical Structure of the Spatial Data Access Problem



The intermediate values of 2, 4, 6 and 8 and their corresponding reciprocals provide additional levels of discrimination and are useful when compromise is required between the two items being pair-wise compared.

A major strength of AHP is the pair-wise comparison where the influence of the elements of a particular level over those of a lower level is measured. The comparison is based on an expert's opinion and the experience gained from the observation and continuous learning of the system behaviour. This leads to the creation of a matrix with 1's occupying the diagonal cells. Detailed explanation of the theoretical foundation, application process and computational approach can be found in Saaty, (1990), Nydick and Hill (1992) and Nigim et al (2003). For each level in the hierarchy, each group was asked to independently decide its preference for one of the pair being compared, using the AHP Scale (Table 1). Each group had to agree on a value based on the AHP Scale. After this, each group presented its pair-wise comparison scores on a flip chart and the values were then compared, discussed and accepted or modified. Discrepancy or judgment bias was eliminated through a simple facilitation technique where the facilitator asks members from each group to explain their positions. Another vote is then taken to check if positions have changed. If the groups' positions do not change, an average of the votes is taken as the result of the comparison. Following this process, two pair-wise comparisons were done for the criteria and the alternatives based on the preference expressed by each group and accepted by majority from both groups.

Table 1: AHP Standard Scale

<table>
<tr><th>Scale</th><th>Definition</th><th>Explanation</th></tr>
<tr><td>1/9</td><td>Extremely less important</td><td rowspan="4">With regard to the reciprocals, if item i has a specific numerical rating when compared with item j, then j has the reciprocal value when compared with i.</td></tr>
<tr><td>1/7</td><td>Very strongly less important</td></tr>
<tr><td>1/5</td><td>Strongly less important</td></tr>
<tr><td>1/3</td><td>Moderately less important</td></tr>
<tr><td>1</td><td>Equally important</td><td>Two activities contribute equally to the objective.</td></tr>
<tr><td>3</td><td>Moderately important</td><td>One is slightly in favour over another.</td></tr>
<tr><td>5</td><td>Strongly important</td><td>One is strongly in favour over another.</td></tr>
<tr><td>7</td><td>Very strongly important</td><td>One is strongly favoured and its dominance is demonstrated in practice.</td></tr>
<tr><td>9</td><td>Extremely important</td><td>The evidence favouring one over another is of the highest possible order of affirmation.</td></tr>
</table>

Source: Saaty, 1990

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Through this deliberative process, priorities were estimated, reflecting the relative impact of the influencing factors on the accessibility components (objectives or criteria). Here, the Eigenvector method was used to normalize the results of the pair-wise comparisons. Thus, the priority vectors for the influencing factors and weights for the accessibility components were calculated using the method of normalized matrix columns (see Ziolkowska, 2008; Nigim et al, 2003).

3. RESULTS AND DISCUSSION

This study was a prioritization application problem and not choice. Thus, AHP was used to determine the relative merit of each of the alternatives in order to focus action on enhancing access to spatial data.

Table 2: Weights of Accessibility Components (Objectives)

	Discoverability	Retrievability	Affordability	Usability	Weights
Discoverability	0.353	0.364	0.273	0.375	0.341
Retrievability	0.353	0.364	0.364	0.375	0.364
Affordability	0.117	0.091	0.091	0.062	0.090
Usability	0.177	0.182	0.273	0.188	0.205
				Total	1.000

Table 2 shows the adjusted matrix and weights of the objectives; and highlights the preference (or the order of importance) of the accessibility components to the respondents. Discoverability and retrievability were considered to be of equal importance (a value of 1). However, discoverability was viewed to be moderately important than affordability and usability. Similarly, retrievability was viewed to be between moderately important and strongly important (value of 4) than affordability and slightly important than usability. In the adjusted matrix (Table 2), retrievability (0.364) is considered most important, followed by discoverability and usability. This result could also reflect an underlying fact that discoverability and retrievability are key constraints to spatial data access. The fact that retrievability ranks slightly higher than discoverability is attributable to the fact that data discoverability takes place in diverse forms, including oral communication, phone or email contacts of the perceived custodian organizations or acquaintances, visit to the organization and offline or online publications. This means, even though there may be better ways of making spatial data discoverable, there are however other alternative means that prospective users adopt to discover data; thus, making discoverability easier than retrievability. With retrievability, 43 respondents indicated that, in most cases, it requires a visit to the custodian organization and the process of accessing the data is time-consuming, cumbersome and often frustrating. The retrieval process often requires the submission of a written application, follow-ups, approval, payments and supply of data. This process can take several weeks to months, and sometimes there is no response. Interestingly, during the interview, data discoverability and a combination of discoverability and institutional bureaucracy were identified as the key constraints to spatial data access. All the respondents indicated that lack of technical capacity (especially networked computer infrastructure) largely accounted for the difficulty associated with discoverability and retrievability. Affordability had the lowest priority (0.090). 39 respondents indicated that most data-holding organizations do not have a pricing policy and therefore prospective data users have to bargain for the price, a situation that often makes the data affordable depending on the perceived use of the data. For example, it was clear from the focus-group discussions that the cost of data is likely to be lower if the perceived use of the data is research, whereas perceived commercial use of data is likely to attract a higher cost. It also emerged from the discussions that sometimes the data exists but it is not explicitly accessible to other organizations or individuals and this diminishes the issue of affordability. However, in such circumstances, some individuals or organizations are able to access through unconventional channels.

Table 3: Weights of Alternatives with respect to Objectives

	Discoverability	Retrievability	Affordability	Usability
A1	0.281	0.275	0.163	0.155
A2	0.155	0.070	0.272	0.300
A3	0.374	0.383	0.187	0.374
A4	0.123	0.182	0.101	0.093
A5	0.065	0.090	0.276	0.078

Key: A1 – A5 represents alternatives (or influencing factors) one to five as below:
A1 = institutional; A2 = policy/legal ; A3 = technical; A4 = socio-cultural; A5 = economic

Table 3 shows the weights (priorities) of the alternatives (influencing factors) with regard to the objectives (accessibility components). Technical issues ranked highest relative to discoverability (0.374), retrievability (0.383) and usability (0.374), but ranked third with regard to affordability. Institutional issues ranked second relative to discoverability and retrievability; fourth on affordability and third on usability. Socio-cultural issues ranked third on retrievability and fifth on affordability while economic issues ranked highest (0.276) on affordability, followed closely by institutional issues (0.272). With reference to discoverability, retrievability and usability, the weights of the technical issues were approximately 25%, 28% and 20% greater than the institutional and policy/legal issues respectively. Clearly, the results show that technical issues impact greatly on accessibility of spatial data; and possibly constitute the greatest constraint to spatial data accessibility. This could also reflect a desire among the respondents to access spatial data online.

Table 4: Overall Priority (Weight) of Influencing Factors on the Main Objective

	Discov.	Retriev.	Afford.	Usability	Weight
A1	0.096	0.100	0.015	0.032	0.243
A2	0.053	0.026	0.025	0.061	0.164
A3	0.128	0.140	0.017	0.076	0.360
A4	0.043	0.066	0.009	0.019	0.137
A5	0.022	0.033	0.025	0.016	0.095

Table 4 shows the products of the criteria weights (Table 2) and the alternative weights (Table 3). The linear sum of the products for each alternative gives the overall weight (score) showing the overall priority (or impact) of the given alternative for achieving the main goal (enhancing access to spatial data). A3 (technical issues) has the highest overall impact (0.360) on enhancing or constraining access to spatial data through its higher overall influence on discoverability, retrievability and usability as already indicated in Table 3 and third highest overall impact on affordability. A1 (institutional issues) has the second highest overall ranking; and shows the second highest overall impact on discoverability and retrievability. A2 (policy/legal issues) had the third overall impact (0.164) on enhancing or constraining access to spatial data but had the highest overall impact on affordability. A4 (socio-cultural issues) had the fourth overall impact on the main objective but ranked third on retrievability.

The utility of AHP in this study was to enable the prioritization of the objectives and alternatives for improvement. From the results and with respect to the objectives (criteria), it is obvious that in distributing limited resources to enhance access to spatial data, discoverability and retrievability should get the top-most priority while affordability should get the least priority. The relevance of this priority ranking is realistic in terms of timeframe for action in the face of limited resources and not the abandonment of the least-ranked objectives. Thus, higher priorities should be given immediately to making spatial data discoverable and retrievable, followed by focus on usability and affordability issues. This is reasonable since SDI development in developing nations need to be approached in a step-wise manner (Williamson et al, 2003). Similarly, with reference to the influencing factors, immediate priority should be given to technical and institutional issues, while the others can be attended to later without totally abandoning them.

The main technical issues raised relate to availability of computers and related software and tools, access to internet and high bandwidth, lack of standards for spatial data, and unavailability of metadata catalogue or clearinghouse that aid the search for data. Consequently, most institutions still keep a huge volume of data in analogue format. Institutional issues raised included low number of skilled personnel, low financing, inter- and intra-institutional power-play and protectiveness, and above all, lack of laid down procedures for collecting, updating and disseminating spatial data. These issues require further study to provide a basis for policy action.

4. CONCLUSION

Improving access to spatial data is of high interest to researchers and policy makers as it is considered as one of the key requirements for sustainability. Multiple stakeholders are involved in the chain of activities ranging from spatial data production to consumption. Therefore, an effort to make spatial data widely accessible necessarily involves multiple decision criteria and requires the input of multiple stakeholders to determine a collectively agreed mechanism and course of action. In this study, AHP was applied to structure a multi-criteria prioritization (ranking) problem with the overall objective of enhancing spatial data accessibility in Ghana from a multi-stakeholder perspective. Through the AHP structure, participants evaluated and ranked (prioritized) five alternatives (called influencing factors in this study) via four criteria (components of accessibility). The alternatives (influencing factors) were institutional, policy/legal, socio-cultural, technical and economic issues, while the criteria were discoverability, retrievability, usability and affordability. Regarding the alternatives, technical issues had the highest priority followed by institutional issues, with economic issues having the least priority. With regard to the criteria, retrievability and discoverability emerged as the objectives requiring the top-most priority while affordability had the least priority. The ranking of the alternatives and the criteria showed a certain level of consistence that technical and institutional issues are currently the greatest constraints to accessing spatial data in Ghana. The results also show that affordability was least important, much as economic issues ranked lowest amongst the alternatives. This means, to enhance access to spatial data in Ghana, immediate effort and scarce resources should be focused on making spatial data discoverable and retrievable by addressing technical and institutional issues. These findings should be useful to actors at policy, management and operational levels interested in enhancing access to spatial data and development of SDI in Ghana.

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