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Challenges and Issues in Spatial Data Infrastructure (SDI) Development in Iraq

Abstract: This paper addresses the nature of Spatial Data Infrastructure (SDI), considered as one of the most important concepts to ensure effective functioning in a modern society. It comprises a set of continually developing methods and procedures providing the geospatial base supporting a country's governmental, environmental, economic, and social activities. In general, the SDI framework consists of the integration of various elements including standards, policies, networks, data, and end users and application areas. The transformation of previously paper-based map data into a digital format, the emergence of GIS, and the Internet and a host of online applications (e.g., environmental impact analysis, navigation, applications of VGI data, governmental efficiency drives) have led to huge leaps forward in SDI development. However, SDI progress can be held back by numerous challenges, both technical and non-technical. The paper outlines these challenges from the perspective of the country of Iraq, where there is an absence of a clear direction towards efficient SDI operation and a lack of knowledge for establishing and managing effective SDI. These challenges could be met by considering and resolving generic issues, identified by the experiences of other nations, by researchers, and by organisations. These issues are investigated and assessed by means of a questionnaire survey and interviews, directed towards important participants in the field of SDI development in the country. The results present the SDI issues in order of relevance to assist developers and users in solving potential SDI and data integration problems within Iraq.

Keywords: SDI, data sharing, Iraq, spatial data, questionnaire survey, technical issues

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1. Introduction

Spatial data infrastructures (SDI) are composed of a wide range of components, not all of them technical in origin, and SDI is complex for reasons other than technicality alone. This complexity is reflected in the different ways in which SDI can specifically be described and defined in the literature. In fact, however, there is remarkable uniformity in the universal definitions of SDI as presented by a range of researchers and practitioners, with several common elements identified as forming the basis of SDI. For instance, [1] viewed SDI as a base collection of technologies, policies and institutional arrangements that facilitate the availability and access to spatial data. A functioning SDI provides a basis for spatial data discovery, evaluation, and application for users and providers within all levels of government, the commercial sector, the non-profit sector, academia, and by citizens in general.

With similar intent, the U.S. Federal Geographic Committee [2] defined SDI as a set of individuals, organisations, technologies and spatial data integrated to facilitate development and dissemination of spatial data, and use of geographic information technologies. [3] stated that SDI consists of the standards, technology, human resources, and policies required to process, distribute, store, and develop the use of spatial datasets. In general, the term SDI involves various activities related to the sharing, discovery, use, integration, and dissemination of spatial data, ensuring that it can be found and accessed easily. SDIs thus play an important role, because such spatial data and information are important in managing government responsibilities, such as for transport, facility networks, crime prevention, urban planning, land use, and public health [4], along with commercial and citizen-based activities.

A national spatial data infrastructure (SDI) facilitates the sharing of public geospatial data within a country. SDIs maintained by regional and local governments may also permit data sharing at different administrative levels [5]. SDI, similar to other information technologies, must be implemented in a manner that allows easy interoperability between diverse systems [6]. The basis of an SDI is the computer system on which the data is stored and accessed by the users. Because SDI is based on large amounts of data distributed throughout many organisations, interoperability is critical.

SDI have developed from initial projects which were directed primarily towards gathering official government data in accessible, centrally-managed, usable databases. Further iterations have chronologically developed through this 'data-concentration' to systems that have prioritised the optimisation of data collection and integration methods – a focus on SDI processes. [7] describe the 'next-generation' SDI as being 'user-centric', moving from consumers of SDI being passive recipients, to the active involvement of users in the management, expansion and enrichment of SDIs.

Although initially the daunting task of creating an SDI was assumed to be a government activity, it is clear that there is a role for the commercial spatial data handling sector, and the contribution of citizen-based initiatives is increasingly

recognised. Volunteer Geographic Information (VGI), for example, voluntarily generated by people to mark locations of interest, is becoming increasingly popular and relevant for SDI integration [8]. VGI has significant potential in contributing to SDI development, especially in countries like Iraq, where such projects have stalled [9]. Further, GIS componentisation offers geospatial services that contribute to data collection and spatial analysis functionality in the general web context. SDI is now characterised by the flexibility of discovery and metadata tools, designed interfaces and quality-control mechanisms for multiple web consumers, from a range of communities and with diverse objectives, from the conservation of the environment and managing funding for agriculture, to mapping production and planning of smart cities [10].

SDIs may be generic or domain specific, may be developed for a specific sector, administrative division (sub-National SDI), or at central or federal government levels (National SDI or NSDI). Overall, demonstrating the inheritance from the earliest SDI initiatives, the most common implementations of formal SDI are on a national scale, driven by the federal or national government. Examples include Australia's ASDI, the NSDI in the USA, Colombia's ICDE, the SNIG in Portugal, South Africa's NSIF, and Malaysia's MyGDI (which has largely been driven by the private sector) [11], and even wider initiatives such as the multi-national INSPIRE Initiative in Europe.

In fact, at a supra-national level, the initiation of the United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM) as a formal framework, established in 2011 under UN convention to explore, improve, and manage Global Geospatial Information Management efforts, has been driven by the perceived need to standardise and integrate SDI initiatives over preceding decades. By incorporating important actors at the top levels of Member Countries, the UNGGIM makes collective choices and establishes guidelines for the use of spatial information within global, regional, and national legal initiatives. The UN adoption of an Integrated Geospatial Information Framework (IGIF) in 2020, designed to strengthen national geospatial information management arrangements within and across Member States at the institutional level and support the implementation of the Sustainable Development Goals, especially in developing countries, is a logical development of the SDI concept to assist in addressing the most critical issues facing our planet.

The significance of SDI as an issue worthy of national attention in Iraq specifically was recognised in 2010, by which date mature and effective SDIs were in place in numerous other jurisdictions around the world. A programme was initiated within the Iraqi Prime Minister's office in that year [12]. In 2012, a strategic partnership of private enterprise, US government agencies and national and regional governments, under the auspices of the Prime Minister's Advisory Committee, met to develop specific proposals, but no implementation of the recommendations which followed the exploratory meeting of this partnership was undertaken.

This paper is intended to provide an overview of the current state of SDI development 10 years after this initial initiative: we first identify the specific challenges of proposing, developing, implementing and reflecting upon SDI, which face the country of Iraq, and then address some of the more practical issues to be considered when tackling such challenges, assessing their relative importance and priorities. The next section, therefore, presents the context for the Iraqi application of the SDI concept, and also identifies and derives the challenges for Iraq. Section 2 outlines the spatial data industry in Iraq, and Section 2.1 presents a comprehensive description of the main spatial data producers in Iraq, and from these sections, along with experienced insight into the state of spatial data handling in Iraq, a daunting list of challenges is derived. In order to address the challenges, generic issues related to SDI and identified by an international range of initiatives are considered. Section 3 introduces these, and in the subsequent section the methodology adopted in this research to evaluate the issues, including a questionnaire survey related to the challenges, is presented. The fifth section shows the results of the survey and follow-up interviews, and concluding remarks are stated in Section 6.

2. The Industry of Spatial Data in Iraq

The first spatial data collection of the modern era (20th century) in Iraq, in the form of standard topographic survey, was carried out towards the end of the First World War, with the help of the Survey of India, and under the control of officers of the British Army. In 1917, the first authorised Iraqi surveying office, known as the Office of the Director General of Surveys, was founded. The work of this office was initially limited to the development of large-scale maps for the region between the two main Iraqi rivers, the Tigris and the Euphrates. Subsequently, in the 1930s, maps were developed for the southern and central parts of Iraq at smaller scales of 1:20,000 and 1:50,000. Photogrammetry, particularly immediately after World War 2, influenced map production processes in Iraq: air survey was undertaken by international agencies at that time, but map creation work was carried out at the Ministry of Irrigation in Baghdad. In addition to deriving a general map at a scale of 1:250,000, the primary production of these operations was photomosaics and agricultural maps at scales of 1:10,000 and 1:20,000 [13].

Updated triangulation and surveying to replace the original Indian mapping survey was undertaken in Iraq in the 1970s to meet modern accuracy standards. A 1974 partnership between Iraq and Poland involved setting up high-order horizontal and vertical control points, survey and photogrammetric work for the whole of Iraq, and topographic mapping at various scales. [13] reported that between 1974 and 1978, Poland helped produce 1500 map sheets at 1:25,000, using Lambert and Transverse Mercator projections. Specific intensification of the horizontal and vertical control point networks in Baghdad and large-scale maps (1:500) for the capital

were also developed. Late 20th century work involved digital conversion of the Baghdad material and GIS mapping using aerial and satellite images.

Spatial information for other cities in Iraq, as well as in in rural areas, is relatively poor; spatial data is often only available in the form of paper sketches, and where maps exist, they are often old or labeled as having limited data. Further, they are often restricted and very difficult to obtain by any prospective user. Where there is a current and unclassified map, the practicalities of exchanging information are typically exacerbated by irregular and non-standard formats, sizes, and designs. Any projects starting to create formal digital spatial datasets confront challenges of massive scope, complexity, and expense, both conceptually and in practice. The merging between the conditions of the methods, the spatial details, producers and consumers are mirrored in the generally held expression: 'data appears to be generated anywhere, but it is difficult to locate data anywhere'. It has been problematic for many users to locate the relevant spatial data, because it is difficult to obtain, or because it is not fit-for-purpose. Despite the perception that spatial data is available in known places, users have been unwilling or unable to access spatial data when it was requested, even internally from their own data centre. In contrast to such lack of transparency in data management, there has been, over the last two decades, considerable openness in technological sectors, including those impacting surveying and spatial data collection. All mapping institutions utilise such current technology, particularly in the field of satellite positioning and navigation, location-based services and GIS software, as well as satellite and aerial image-based data. These contemporary developments have resulted in flexibility and unpredictability in map development, and a lack of centralisation and standardisation, combined with the fact that many state agencies have acquired systems and equipment without a defined scientific strategy for most effectively employing geographic information systems.

In recent years, for example, the General Authority for Surveying in Iraq made rudimentary attempts to update and produce topographic and thematic maps using commercial satellite images from missions such as Landsat and Sentinel. In addition, open-source data such as SRTM and OSM network data were utilised to create and update maps. The General Authority for Surveying has initiated a national project to produce topographic maps at a scale of 1:100,000 for Iraq, as well as to construct a national geographical centre for the project and associated databases utilising a more integrated approach to technology.

However, Iraq currently still lacks a clear vision in the fields of map production and database management, partly due to the numerous and duplicating agencies that deal with these issues, as well as a lack of centralisation that defines national standards in map production, along with the absence of a national centre that collects all information and databases.

For most agencies, the diverse information and data centres attached to separate agencies do not function as in the initial 2012 plan discussed in Section 1 above. These centres have a comparatively lower profile than other sectoral divisions, lack

effective leadership for spatial data regulation, and are exposed to the absence of a firmly defined legislative framework for handling spatial data within the enterprise. Lack of coordination between separate agencies (e.g. government ministries, private companies, academia) is also reflected in Iraq within such organisations. Duplication of data collection and holdings, mismanagement of technological resources, proprietorial ownership of data, lack of financial support, and lack of experienced personnel and SDI 'champion' are all examples of the issues holding back SDI in Iraq.

The creation and development of a feasible SDI is always a hope for the future, as it is not seen as a 'rapid' project by decision makers. There is, however, an immediate need to create a comprehensive, integrated and consistent legislation to provide precise guidelines on governance and use of spatial data in Iraq.

2.1. The Main Spatial Data Producers in Iraq

The observations outlined above relate to the current state of spatial data handling in Iraq, and these shortcomings obviously have an effect on progress with SDI development in the nation. It is only in the 21st century that geographic information systems and digital spatial data have been widely adopted in Iraq, albeit with an absence of clear goals and without any central plan of action. Governmental institutions have recently taken serious steps for dealing with spatial data and developing geo-databases, and it is such institutions which have the incentive to collaborate in developing SDI, and the experience to actually utilise it.

Currently in Iraq, there are many data sourcing bodies responsible for producing and maintaining spatial data, pre-eminent of which is the Director General of Surveys. This is responsible for recording land registration and ownership, including production of cadastral mapping, and has developed geodetic networks. It has also been given responsibility for developing GIS systems related to its work and meeting the needs for modernisation [14]. Separate geographic information (GIS) centres at a regional level have been also established on an ad-hoc basis in Iraq to treat and organize spatial information through digital maps linked with databases. The Karbala geographic portal, for example, was launched in 2015 to include the creation of a geographic information system for the Karbala governorate. This project, which is funded by the United Nations Development Program Development (UNDP) in Iraq, involves more than 20 departments from the governorate, including the municipality itself, oil, electricity and other utilities, and health agencies [15].

The national Ministry of Construction, Housing and General Municipalities has long-standing experience in the field of using geographic information systems and development of geo-spatial datasets, and has been given responsibility for monitoring and implementation of the master plans of cities across the country. Production and updating of detailed plans for water and sewage networks in Iraq is another role of this ministry [16]. The mayoralty of the capital Baghdad can be considered as another major spatial data handling agency. It has a special GIS branch, established in 2003, with the task of converting all paper map records into digital format,

especially those covering water and sewage infrastructure, roads, basic design for the city of Baghdad, waste collection and treatment, and service centres. The state commission for geological survey is a further important source of spatial data, and expertise. One of the biggest projects achieved by this commission is the completion of the regional geological survey for Iraq at a scale of 1:100,000. It also prepares other digital topographic maps, databases and associated digital documents through its practical map production and printing unit [17].

Each of the organisations mentioned here has GIS experience and expertise, albeit to varying levels. Unfortunately, there has been, and continues to be, a lack of cooperation between them. And even within the groups themselves there can be inconsistency and lack of standardization, with separate users from the same organisation demanding new datasets which are actually already held there. Further, there is duplication in some projects. For instance, the main responsibility of the Director General of Surveys is producing and developing topographic maps, but the Geological Survey has carried out similar digital topographic mapping and database development. Such a lack of cooperation between the spatial data producers leads to wasted money and effort, and the duplication of work throughout Iraq.

In data processing and storage, there is a great deal of data redundancy, yet also enormous gaps in spatial data, by area and theme. Most institutions still keep their spatial information as physical copies, rather than in networked or cloud-based data stores. Because a key goal of creating an SDI is to initiate a sound atmosphere in which all, consumers and developers of spatial information alike, can collaborate with each other in a cost-effective manner in order to obtain better performance, it is an urgent necessity to accelerate SDI adoption in Iraq.

3. Issues Related to Spatial Data Infrastructure

Having presented the challenges in the context of Iraq, it should be possible to explore the issues identified by numerous researchers and practitioners as being central to SDI development worldwide [18]. These issues will then be presented to participants in Iraqi initiatives in order to understand their views on how renewed SDI development can best be implemented, and to what extent concentration on specific issues can address the challenges.

A range of technical issues related to SDI implementation have been identified over many years, both from conceptual perspectives and from pragmatic experiences. These include problems related to variable data quality; the handling of coordinate reference systems, scale and projection; the recording of metadata and semantic content; the impact of external standards and ideas of interoperability; the adoption of common data models and formats; the storage, querying, distribution and dissemination of data; and the development of service-oriented architectures beyond the data archives [19, 20].

Non-technical issues which have been addressed by SDI developers and managers are even more extensive and potentially intractable. These include legal, policy, social, human and institutional problems. Legal issues can arise from the initiation of national SDI, if there is contemporary legislation on data access and privacy. Even if such data protection aspects can be dealt with, the data itself may have intellectual property rights, copyright, licensing and pricing factors which can fundamentally affect utility. Associated policies with regard to overall national, regional and local governance, the role of political leadership and societal stability, and the relative impact of civil servants, consultants and politicians are also impacted by the legislative framework. Further policy and institutional impacts on SDI effectiveness can include aspects such as level of intra-governmental/inter-ministry collaboration along with public/private sector interaction; mutual awareness of analogous activity within relevant organisations; and associated funding models [19]. The interaction and common agreements necessary to manage SDI rely on levels of trust amongst all participants; scale and viability of setting up such an infrastructure; actual communication networks to allow for data handling; recognition of the value of intended, improved decision-making; and commitment to reducing duplication and redundancy in data.

Wider social and human factors have been identified [20], including societal and cultural norms which affect data distribution and use; general experience, education, background and awareness of the stakeholders; and level of societal development and strategic economic planning. In many cases organisations use different standards, policies, and arrangements to manage and maintain datasets. The diversity of non-technical topics which are utilised to share and store datasets also affect data integration. It is notable, however, that the issues presented in this section have been recorded as affecting all efforts at SDI, regardless of nation, scale of SDI project, or stage of evolution of SDI implementation and use. The issues should, therefore, be capable of being presented to the people and organisations in Iraq, and some evaluation of their relative importance (and a listing of their priority) should result. There is a need to evaluate these challenges of spatial data integration in specific circumstances and this relies on interaction with and reflection by the human component of SDI. But it is hoped that identifying and considering some of the specific issues in the context of the experiences and opinions of expert stakeholders will be valuable in helping SDI projects in Iraq progress.

This topic requires an initial exploration of how efficient the exchange of, and cooperation with, Iraqi spatial data is. An effort will be made to clarify existing collaborations and collective agreements and recognise their effectiveness and sustainability. To meet the aim of the study, a number of important and experienced professionals were contacted, to determine their opinion of the most important issues facing SDI, and ascertain their understanding of why SDI implementation in Iraq is proving problematic. Such opinions were sought by means of a questionnaire survey and follow-up interviews.

4. Methodology and Datasets

The study described in this paper helped to confirm the observations presented in the previous sections, and further elucidated the views of those involved in spatial data handling in Iraq, particularly with regard to the improvements required to effectively progress with SDI. The primary method used was a questionnaire survey directed towards representatives of the main players, along with interviews where further clarification was sought. Questionnaire surveys allow for participants to respond to both closed and open-ended questions. As a data collection tool, a questionnaire has a number of advantages, being cheaper and quicker to administer than direct contact, with no interviewer influence or variability, and is convenient for those completing it. However, it also has a number of disadvantages, including a lack of prompting or clarification, no facility to allow an issue to be explored (respondents do not want to write much, even in open-ended questions), limited in length with questions restricted to salient issues, anonymity and inability to identify specific characteristics of respondents, risk of missing data, and potentially low response rates [21].

The intention of the questionnaire survey presented here was to validate the spatial data integration issues identified in Section 3 above within the Iraqi SDI context, asking for responses to a series of five metrics, which are the key reference points for the questionnaire. The major focus of the survey was to determine the perceived level of impact of a series of potential problems and issues faced by SDI professionals aiming to develop the concept further within Iraq. Each question prompted one of five possible responses, indicating the level of relevance of a particular issue to the improved development of SDI:

1) No Relevance,
2) Low Relevance,
3) Moderate Relevance,
4) High Relevance,
5) I don't know.

20 questionnaires were sent out to selected Iraqi spatial data producers and consumers, in governmental organisations, academia, and capital city and provincial administrations, during October to December 2020. As the number of spatial data specialists is somewhat small in Iraq, it was often difficult to locate a suitable individual in the organisation to complete the questionnaire. The target individuals were selected based on their ability to contribute to the research questions and understanding of the topic under investigation. As a result, one of the most critical jobs during the research design phase was to identify suitable volunteers. Selection was based on matching the role of individuals with the topics addressed by the questionnaire, and the background understanding of the nature of SDI which informs the study. Further aspects of questionnaire design, relating to length, distribution

arrangements, visual impact, and personal focus were also considered. As with all such data collection exercises, it is the variability of the subjects themselves which can lead to particular insights, and this was clearly a factor in the range of responses: for example, ensuring a range of educational backgrounds and academic achievement of the participants was important; and those in academia supplied differing responses to those in industry. However, the analysis was done and results reported in the next section at the full cohort level.

Contextual information about a participant's organisation, its expertise in the area of spatial data handling, and familiarity with the topic of spatial data infrastructure (SDI), were, therefore, sought. An 85% response rate was achieved. Figure 1 shows the profile of the target group: it is hoped that a firmer understanding of the perceived factors affecting SDI implementation in Iraq can be developed from this wide-ranging group of questionnaire recipients. The intention is to determine the most critical factors which are preventing progress on SDI development, with the expectation that such factors can be addressed in a positive way in the near future.

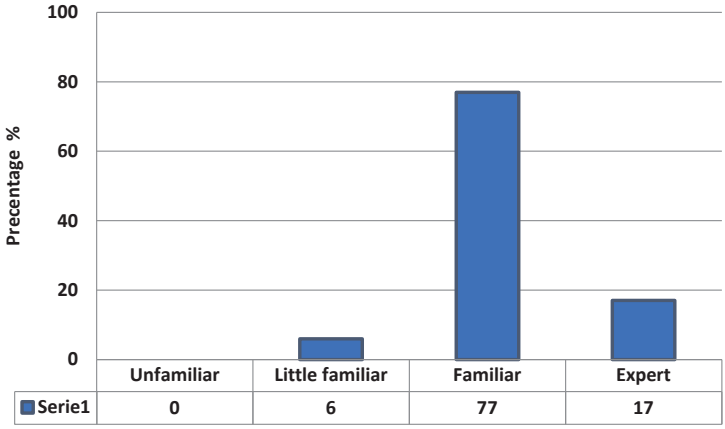

Fig. 1. The familiarity with SDI

Follow-up interviews were also used to gather qualitative information to supplement, clarify, and confirm the quantitative data collected by the questionnaire, and engage in in-depth discourse. During interviews a researcher may closely consider discussion in real-time and expand on initial superficial reactions to derive detailed findings [22]. In this study, 10 people from different organisations were interviewed, a sub-set of those who answered the questionnaire. The interview was semi-structured, and the respondents were informed that the interview would address their experiences and opinions regarding spatial data infrastructures. The majority of interviewees consented to an audio recording of the interview, but this wasn't always practicable, so notes were taken instead. As a semi-structured interview, there was only a limited set of three questions designed to provoke wider-ranging discussion:

"what are the three main issues which are holding back SDI development in Iraq?"; "how do you think that a more integrated approach to spatial data handling might happen?"; and "what would be the applications, and end benefits, of having a formal SDI in Iraq?". The answers to these questions and issues raised during discussion are presented in the next section as direct quotes and have been used to validate the outcomes of the questionnaire analysis.

5. Results Analysis

The responses to the questionnaire survey were examined as a whole: there is no distinction made amongst the participants in terms of job grade, experience, age etc. The major focus was on highlighting the factors which were identified, by researchers and practitioners over many years, as being most critical in terms of obstructing SDI implementation.

The overall outcomes revealed that it is technical issues which are identified as the most relevant (Fig. 2). Data quality (71%), metadata (59%), and data model (59%), were selected as 'highly relevant issues' by the majority of participants. A main reason for this is that these are quite common terms used to address or to discuss datasets, so our contention is that familiarity with these concepts may make them score higher than other, equally important factors, identified by [18] which may be less recognisable (heterogeneity, vertical topology, semantics). Some of these latter issues were actually acknowledged as being uncertain ('I don't know') by several participants. The technical issues which were regarded as being of less relevance as barriers to implementation included those which are indeed straightforward to overcome: the integration of data of different projection, reference systems and formats can be easily achieved with contemporary software. Each of these was majority scored at above 40% in the 'moderate relevance' category – the most common response for these issues.

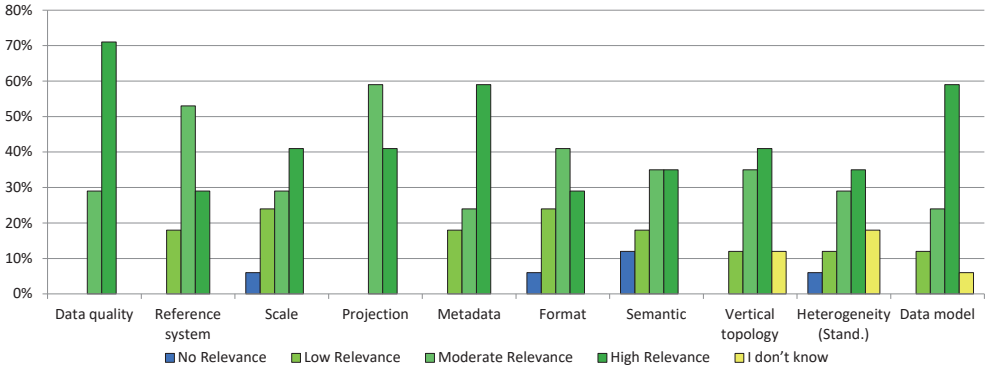

Fig. 2. Technical issues relevant to SDI

In terms of institutional issues relevant to SDI, there was greater unanimity in that each highlighted factor was 'highly relevant': the majority of respondents scored each of the five issues in this way (collaboration models (53%), funding model (53%), linkage between data management units (65%), awareness of data existence (59%), and effective standards (53%)), at above 50% (Fig. 3).

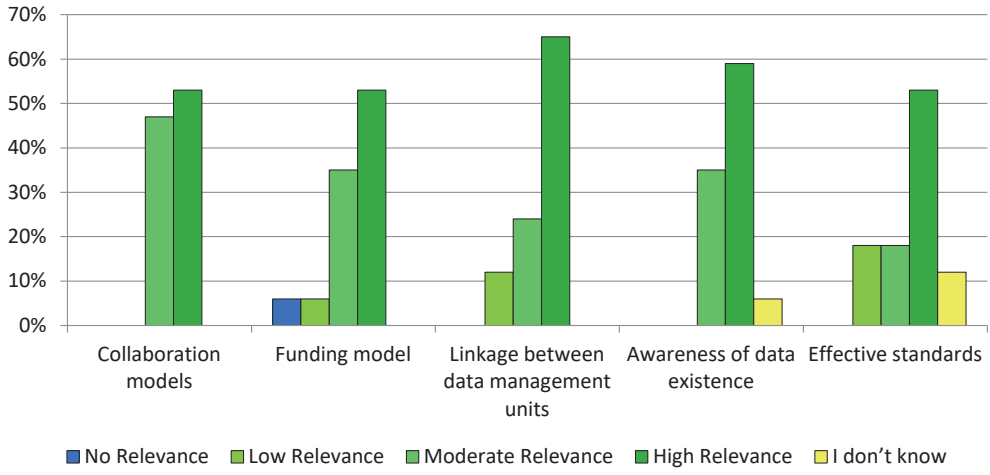

Fig. 3. Institutional issues relevant to SDI

There was more uncertainty about social aspects and a lower consideration of their importance (Fig. 4), with only experience (41% of responders) and cultural issues (35% of responders) being considered as highly relevant. This is probably because the improvement in interoperability and the value of web services are based on experience with open standards and specifications. In addition, experience is necessary for users to expand their use of SDI, such as downloading data and building new framework data layers. The cultural aspects may be important for organisations and communities for developing data sharing mechanisms and common standards between several organisations. With regards to capacity building activities and background of stakeholder, 53% and 35% of respondents choose them, respectively, as of moderate relevance. These results are more uncertain despite the fact that each issue is considered by many to be essential to consider for developing, planning and implementation of SDI.

With regard to legal issues (Fig. 5), the majority of the responses considered rights restrictions and responsibilities, data access, privacy, and licensing as 'highly relevant'. Once again, those categories which are less well understood ('I don't know') had a lower score in terms of relevance to SDI implementation. Legislation issues, and properties (sustainable development) and policy, have majority 'moderate relevance' responses, whilst for political stability and pricing the 'moderately relevant' response is the highest response.

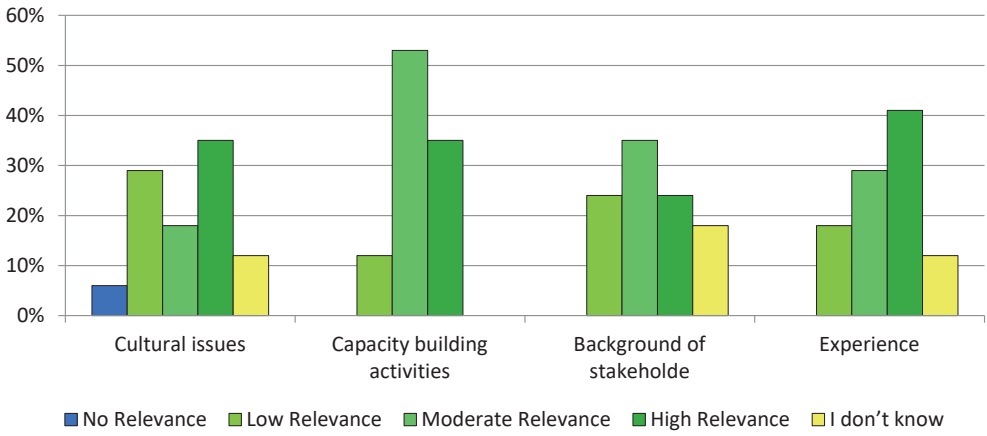

Fig. 4. Social issues relevant to SDI

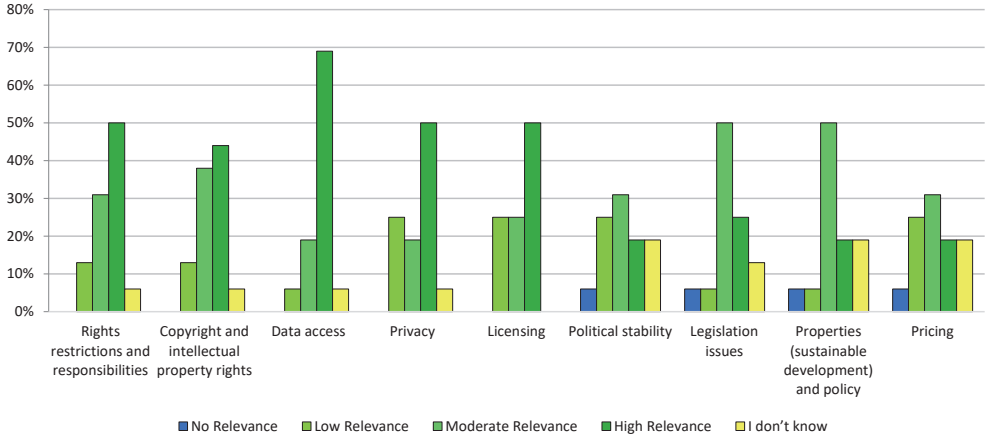

Fig. 5. Legal issues relevant to SDI

Figure 6 shows the rating frequency for the exchange and sharing aspects: absence of trust (59%), search to needed data (59%), protection of privacy in data (53%), network communication infrastructure (71%), improved decision making (59%), and reduced duplication in resources (59%) were considered 'highly relevant' by the majority, whilst the only other issue, single source of verified data, was identified as 'moderately relevant' by a majority of responders.

Whilst the questionnaire survey was able to assess the direct response of participants to particular issues and note their relative 'scoring' of importance, it was the follow-up interviews which gave more insight into the personal opinions of those involved in the study.

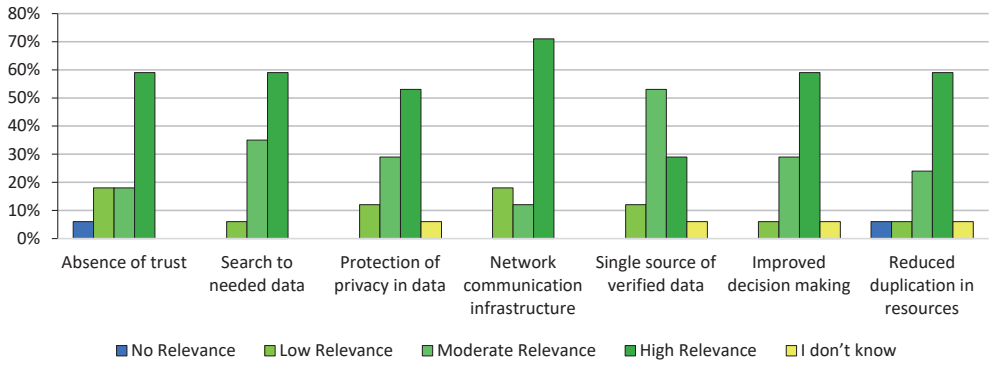

Fig. 6. Exchange and sharing issues relevant to SDI

The obstacles to successful SDI implementation were the focus of the first interview question, so it was of interest to note the more extensive comments which arose about issues holding back SDI development in Iraq. From a technical perspective respondents lamented the "lack of connected geographic information communication systems and (common) software." Even when agreement could be reached on technical specifications, it was felt that strategic "preparation and maintenance of computer-based systems that can work for decades" was lacking. "Differences in data type and a lack of electronic sharing, and absence of defined or unified methods for data archiving" were also highlighted. Specific technical aspects mentioned reflected the issues raised in the questionnaire, and the relation with more administrative shortcomings: "reference system and scale, data quality, metadata, funding model, and connectivity between data management units".

One respondent claimed that "technical, institutional, and financial obstacles impede the development of SDI in Iraq, but financial obstacles are the most significant [...] because there is technology and technical expertise in Iraq: financial problems will have (the most) significant impact on infrastructure development."

A range of related administrative issues were highlighted in the discussion: there is a perceived need for "a single Iraqi SDI centre that houses all of the country's ministries and fundamental utilities that deal with geographical data [...] (with) consistent standards for the usage and representation of spatial data." More specific items were emphasised by several respondents. "The absence of labor rules, that enable workers to generate and distribute geographical data in a legal framework, is the major impediment to the growth of SDI in Iraq." Other capacity-related issues are noted also: "a specialist cadre at the level of programmers and GIS engineers at each institution (is needed)."

When asked how more integration might be achieved, some respondents suggested a need for a "single specialised dedicated national centre, with data transmitted to (it) on a regular basis." "Spatial data will be gathered, produced, stored, and updated on national central servers within an ordered framework at this facility."

Others suggested a more decentralized structure with "a generic design for a database for each institution, with the authorities and responsibilities of each agency noted." This array of individual agencies should include "the engagement of higher government agencies (i.e., cabinet level) [...] ministries, as well as the industrial and investment sectors." However, there is a recognition of the need for uniformity of approach, including the imposition of standards "in all aspects: hardware, software, data (spatial and non-spatial), meta-data, policy, and security."

The usual and expected responses were given to the enquiries about how a mature SDI could be used, and its benefits: in general terms it was suggested that "achieving any geospatial goal" and "enhancing the degree of future planning to achieve high levels of progress" should be the aims. More specifically, there were hopes for "decreasing planning conflict", "assessing data duplication and information loss", encouraging "e-government (allowing) easier access to information and facilitating decision-making", and Iraqi priorities such as "disaster response; transportation management; water, gas and electric planning; public protection; natural resource management; telecommunications infrastructure."

The questionnaires presented particular issues and topics, asking the respondents to gauge their relative importance and impact. The results were more amenable to quantitative analysis, which revealed the stated particular technical, legal, institutional, social, and data sharing issues which most interested those questioned. The interview responses, on the other hand, also focused on some of the more specific practical issues holding back SDI implementation – lack of a coordinating SDI centre, the multiplicity of GIS software and data formats – but also addressed more generic policy-influenced practices – the need for e-government and the lack of a dedicated financial budget for SDI.

The comments submitted by respondents, both in questionnaires and interviews, reveal the difficulties for SDI implementation in Iraq. A GI strategy has not yet been enacted into law, so it is challenging to put standards for data collection and sharing into practice. Data sharing is still insufficient since geographic data producers continue to acquire data on an individual basis, resulting in repetition in the data development process. The nature of the territory itself – Iraq is a land of contrasts with a variety of physical, social, and cultural characteristics – is amplified by the fact that each region of the country has unique data requirements and is sometimes unwilling to share information unless they have something to gain from it.

6. Discussion and Conclusion

This research aimed to assess opinions about the main challenges and issues that affect the development of SDI in Iraq, basing these potential spatial data integration issues on those identified and experienced by implementations around the world. The survey of opinions was carried out through questionnaire survey and follow-up interviews for the opinion of experts in the spatial data field. The experts consulted

have a significant role in the development of an effective SDI framework across the nation – their opinions as reflected in this survey are important to take on board. The survey results revealed that all of the SDI issues listed are regarded as moderately or highly relevant: none were identified as of no or low relevance. However, some issues were specifically identifiable as highly important to consider when establishing SDI. In Iraq, attention must be paid to the quality of data, before stakeholders would feel confident about SDI maturity. Effective inter-departmental collaboration (linkage) is also considered as essential to pay attention to, whilst access to data must be made efficient. These data-related issues are strongly affected by other high-relevance factors, notably those related to exchange and sharing, a mixture of technical and non-technical factors. Thus, respondents identified network communication infrastructure, search facility, and fostering of an environment of trust amongst stakeholders, as being critical. Both the questionnaire surveys and the interviews revealed the nature and level of importance of all of these factors, and the need for urgent and focused action, as suggested by the participants in this study, is clear.

It is suggested that all the particular issues need to be addressed for timely SDI development, along with attention to more general, structural practices. If an effective national spatial data infrastructure can be established, experience shows that there are significant further benefits, resources and structures which can be developed and exploited. Moving beyond a mechanistically managed centralised database of spatial information, a cultural change in considering spatial issues could arise, or even be encouraged. This is the fundamental aim of the IGIF, as proposed by the UN. Establishing a central geospatial data bank for sharing and exchanging data over different governmental sectors can provide a secure, safe and easy scientific database for academia and researchers interested in the field of geospatial data handling. This may require a more mature environment to improve the capability of all spatial data users by organising training, workshops and meetings to develop abilities for producing, transferring, and sharing spatial data. In addition, all governmental organisations, especially those specialists in the fields of spatial data, should be directed to establish GIS research centres for providing an appropriate scientific atmosphere, encouraging research and regular practical application. It is also important to adjust the current legislation so that it is not a barrier, but a framework for SDI development. In this regard, common SDI concepts and experiences can be considered and applied in an Iraqi implementation. The specific problems outlined in this paper, identified by a survey of the major players, and the opinions of the respondents, need to be addressed. The widening of the scope of SDI development to include the addressing of cultural issues; the identification of cost-benefit analysis for the country's economy and decision-making capabilities; and the increasing importance of VGI-sourced data derived from citizen observations, web technologies and location-based services; all indicate that further research is needed to match the general recommendations promoted by UN and international experts with local aspects of spatial data handling within the nation of Iraq.

It is therefore important to note that, despite the formalised efforts (summarised earlier in this paper) of many agencies in the past 25 years of SDI research, policy-making and implementation, the nature, impact and use of SDIs is not fixed. Contemporary technological changes, in particular, can have an effect on SDI, regardless of the stage of adoption. [23], for example, in addition to highlighting the role of VGI, as mentioned above, also suggests that the Internet of Things (IoT), the broadening range of activity-specific private sector data sets, streaming sensors in the instrumented city, and the expansion of high-resolution satellite data, will all affect data provision in SDIs. The subsequent handling of such data, in the Cloud, accessed through APIs, triggered by event-driven algorithms, and streamed in massive amounts, is also potentially problematic. The adoption of artificial intelligence (AI) will lead to further development in the modelling, design, implementation and use of SDIs, whilst the role of maturing standards is always of importance [24].

In Iraq, these issues may well be overwhelming. This paper has concentrated on the standard SDI cookbook approach, introduced by the Global Spatial Data Infrastructure Association twenty years ago [1], and our survey has shown that is difficult to adopt most of the recommended practices presented there: the potential for SDI implementation remains unfulfilled, and it is likely that the overwhelming and highly variable nature of the more recent factors mentioned in the previous paragraph would only cause further delay and uncertainty in adopting a national SDI project. It is hoped that resources can be directed towards overcoming the more specific barriers highlighted in this study, ensuring that the technical, social, cultural and economic conditions are appropriate for a successful Iraqi SDI.

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