FACTORS IMPEDING THE DEVELOPMENT OF
OMAN SPATIAL DATA INFRASTRUCTURE

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I lovingly dedicate this thesis to my family who supported me at each step of the way to achieve this level.

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ABSTRACT

Spatial Data Infrastructure (SDI) is an innovative concept introduced more than twenty years ago to allow the sharing and reuse of geospatial data. The National Spatial Data Infrastructure (NSDI), an SDI expanded to the national level, is now widely considered as an essential basic infrastructure for a country in this information era. To date countries all over the world, irrespective of their size, economic strength, political stability and population size, have developed, developing or considering developing their own SDI. A number of developed countries had successfully developed an impressive operational SDI while others are still progressively developing theirs. Yet for other countries the SDI development still remains an innovative concept. Understandably, besides the political and economic factors, many interrelated technical and non-technical factors can affect the development of SDI, the complexity of which can increase with the increase in the level of jurisdictions involved in spatial data sharing. Oman was one of the countries that had taken up the early initiative but unfortunately all that was known of the initiative was some feasibility studies conducted by non-national institution. Therefore this research has attempted to investigate the factors impeding the SDI development of Oman as an effort to revive the initiative to develop an operational Oman SDI, seen as an integral infrastructure to Oman's future development and an important component in disaster and environmental management. Through this study, it was found that SDI is about communications between SDI participants to share spatial data. Through the thorough review of the data gathered from interviews and questionnaires, this research methodology was supported by systematic inspection and analysis of the essential data. The main stumbling block to Oman's effort in building the SDI is the non-technical factors, including the human aspects entailing the lack of knowledge and awareness of spatial data and use of GIS, lack of knowledge on SDI concept and SDI benefits, and also the lack of cooperation, collaboration and coordination among the participants. It can be concluded that the lack of knowledge and awareness make communication between SDI participants difficult, thus almost impossible for cooperation, collaboration and coordination. This had left Oman with no option but to leave the initiative as an innovative concept, are now identified to be given the highest priority to enable Oman to pave the way forward.

ABSTRAK

Infrastruktur data spatial (SDI) adalah konsep inovatif yang diperkenalkan lebih dua puluh tahun dahulu untuk membolehkan perkongsian dan penggunaan semula data spasial. Infrastruktur data spatial Negara (NSDI), iaitu SDI yang diperkembangkan ke peringkat nasional kini dianggap secara meluas sebagai suatu infrastruktur asas yang penting bagi sesebuah negara dalam era maklumat ini. Kini negara-negara serata dunia, tanpa mengira keluasan, kekuatan ekonomi, kestabilan politik dan saiz penduduknya, telah, sedang dan akan membangunkan SDI masing-masing. Beberapa negara maju telah berjaya membangunkan SDI mengagumkan yang kini beroperasi sementara negara-negara lain masih terus membangunkan SDI mereka. Namun bagi negara-negara lain pula, pembangunan SDI mereka masih lagi tinggal sebagai suatu konsep inovatif. Mudah untuk difahami bahawa, selain dari faktor-faktor politik dan ekonomi, banyak faktor-faktor teknikal dan bukan teknikal yang boleh mempengaruhi pembangunan sesuatu SDI. kerumitan bertambah dengan meningkatnya tahap bidang kuasa yang terlibat dalam perkongsian data spatial. Oman adalah salah satu dari negara yang telah memulakan inisiatif awal tetapi malang sekali apa yang diketahui mengenai inisiatif ini hanya beberapa kajian kemungkinan yang telah dilaksanakan oleh institusi asing. Oleh demikian, kajian ini menyiasat faktor-faktor yang menghalang pembangunan SDI Oman sebagai usaha untuk menghidupkan semula inisiatif bagi membangunkan SDI Oman yang beroperasi dan dilihat sebagai infrastruktur penting untuk pembangunan Oman pada masa hadapan serta sebagai komponen penting dalam pengurusan persekitaran dan bencana alam. Melalui kajian ini, didapati SDI adalah berkenaan komunikasi antara peserta-peserta SDI untuk berkongsi data spatial. Melalui ulasan menyeluruh data yang diperolehi dari temuramah dan soalselidik, metodologi kajian ini di sokong dengan penelitian dan analisis yang sistematik terhadap data penting hanya mendapati penghalang utama dalam usaha Oman untuk membangunkan SDI adalah faktor-faktor bukan teknikal, lebih tepat lagi, aspek-aspek berkaitan manusia seperti kekurangan pengetahuan dan kesedaran mengenai data spatial dan penggunaan GIS, kekurangan pengetahuan tentang SDI konsep dan faedah SDI, dan juga kekurangan kerjasama, kolobrasi dan kodinasi antara peserta-peserta. Dapat disimpulkan bahawa kekurangan pengetahuan dan kesedaran menjadikan komunikasi antara peserta-peserta SDI susah, hinggakan hampir tiada kemungkinan untuk berkerjasama, berkolobrasi dan berkodinasi. Perkara ini menyebabkan Oman tiada pilihan tetapi terpaksa meninggalkan inisiatif tersebut sebagai konsep inovatif sahaja. Kini faktor-faktor ini dikenalpasti sebagai keutamaan terpenting yang membolehkan Oman mencorakkan halatuju ke hadapan.

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LIST OF ABBREVIATION

AD-SDI   -   Abu Dhabi Spatial Data Infrastructure

ADSIC   -   Abu Dhabi Systems and Information Centre

AGI   -   Association for Geographic Information

ANZLIC   -   Australia New Zealand Land Information Council

APSDI   -   Asia-Pacific Spatial Data Infrastructure

APSMA   -   Australia Public Sector Mapping Agency

ASDI   -   Australia SDI

BSDI   -   Bahrain Spatial Data Infrastructure

CCOG   -   Canadian Council on Geomatics

CGDI   -   Canadian Geospatial Data Infrastructure

CGIS   -   Centre for GIS

CMI&C   -   Constriction Material Industry & contracting

CNIG   -   National Centre for Geographic Information

CSDGM   -   Content Standards for Digital Geospatial Metadata

DBMS   -   Database Management System

DGI   -   Digital Geographic Information

DGIWG   -   Digital Geographic Information Working Group

DGMAN   -   Directorate General of Meteorology and Air Navigation

DEM   -   Digital Elevation Model

DIGEST   -   Digital Geographic Information Exchange standard

DM   -   Dhofar Municipality

DNF   -   Digital National Framework

DTED   -   Digital Terrain Elevation Data

DTM   -   Digital Terrain Model

EDB   -   Economic Development Board

EGII   -   European Geographic Information Infrastructure

eGU	-	e-Government Unit
EU	-	European Union
EUROGI	-	European Umbrella Organisation for Geographic
FACC	-	Feature and Attribute Coding Catalogue
FGDC	-	Federal Geographic Data Committee
FIPS	-	Federal Information Processing Standard
FRC	-	Future Requirement Committee
FUGRO	-	FUGRO Middle East and Partners company
GCC	-	Gulf Cooperation Countries
GDI	-	Geographical Data Infrastructure
GEMINI	-	Geo-spatial Metadata Interoperability Initiative
GII	-	Geographical Information Infrastructure
GIS	-	Geographic Information System
GML	-	Geography Markup Language
GNP	-	Gross Nation Product
GPS	-	Geographic Positional System
GSDI	-	Global Spatial Data Infrastructure
HM	-	His Majesty
IACG	-	Inter-Agency Committee on Geomatics
ICSM	-	Intergovernmental Committee of Surveying and Mapping
ICT	-	Information and Communication Technologies
INSPIRE	-	Infrastructure for Spatial Information in Europe
ISO	-	International Organization for Standardization
ITA	-	Information Technology Authority
MaCGDI	-	Malaysia Canter for Geospatial Infrastructure
MECA	-	Ministry of Environment and Climate Affairs
MGS	-	Muscat Geo System Company
MM	-	Muscat Municipality
MOAG	-	Ministry of Agricultural
MOH	-	Ministry of Housing
MOHR	-	Ministry of Heritage
MOI	-	Ministry of Inertial
MONE	-	Ministry of National Economy
MORM&WR	-	Ministry of Regional Municipalities and water Resources

MOTC	-	Ministry of transport and communication
MWS	-	Military Welfare Service
MyGDI	-	Malaysian Geospatial Data Infrastructure
MZEC	-	Mazown Electric Company
NaLIS	-	National Infrastructure for Land Information System
NCSP	-	National Centre for Spatial Planing
NGDB	-	National Geographic Data Base
NGDF	-	National Geospatial Data Framework
NGISA	-	National Geographic Information System Authority
NGISSC	-	National GIS Steering Committee
NHO	-	National Hydrographic Office
NIT	-	Navigation Information Technology
NTDB	-	National Topographic Database
NSA	-	National Survey Authority
NSDI	-	National Spatial Data Infrastructure
NSGI	-	Portugal National System for Geographic Information
Omantel	-	Oman telecommunication company
ONSDI	-	Oman National Spatial Database Infrastructure
ORDBMS	-	Object-Relational Database Management System
PCGIAP	-	Permanent Committee on GIS Infrastructure for Asia and the Pacific
PCGIAP	-	Infrastructure of Geographic Information Systems Asia and the Pacific
PDO	-	Petroleum Development for Oman
RDBMS	-	Relational Database Management system
RSDI	-	Regional National Spatial Data Infrastructure
SCTP	-	Supreme Committee of Town Planning
SDI	-	Spatial Data Infrastructure
SI	-	Spatial Information
SIPC	-	Sohar Industry Port company
SQL	-	Structured Query Language
SQU- COA	-	College of Arts – Sultan Qaboose University
SQU-RSC	-	Remote Sensing Center– Sultan Qaboose University
SVG	-	Scalable Vector Graphics

SWOT	-	Strength Weakness Opportunities Thrust Analysis
TDB	-	Topographic Database
UAE	-	United Arab Emirates
UK	-	United Kingdom
UN	-	United Nation
URA	-	User Requirements Analyses
URIs	-	Uniform Resource Identifiers
USA	-	United States of America
UTM	-	Universal Transverse Mercator
WSDH	-	Water Supply Dhofar

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CHAPTER 1

INTRODUCTION

1.1   Background

Spatial Data Infrastructure (SDI) is an innovative concept introduced more than twenty years ago to allow the sharing and reuse of geo-spatial data. Developed countries such as Australia, United States of America (USA), Canada and many European countries have enjoyed many benefits from their successful operational SDIs. The National Spatial Data Infrastructure (NSDI) which refers to the SDI implemented at national level is not merely a database but includes the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilisation of geospatial data (USA, 1994). It has become an important part of the infrastructure for a country. Spatial data infrastructure is indispensable for providing geospatial information for government and civilian decision making. It is essential for optimising land use, stimulating economic activity, managing natural disasters and hazards and for developing environmental policy. It has often been quoted that as much as eighty percent of all local government decisions are spatial in nature (FGDC, 1996; O'Flaherty *et al*., 2006). As such, as many as more than 120 countries (Crompvoet, 2006) in the world have attempted to develop their own national SDI. However, many countries faced some kind of problems at different stages of the SDI development. It was observed that countries with strong and stable economy with high demand and use of spatial data mostly managed to eliminate the various problems pertaining to the SDI development.

Transitional economies such as Brazil have also succeeded in developing their SDI (Davis and Fonseca, 2006). More recently Uganda and Jordan have begun developing their SDI. The Gulf Cooperation Countries (GCC) of Qatar, United Arab Emirates (UAE), Sultanate of Oman, Bahrain, Saudi Arabia and Kuwait had begun developing their SDI systems. Qatar was one of the earliest countries to pioneer SDI development. Besides Qatar, Bahrain and Abu Dhabi in the UAE have also succeeded.

SDIs have been developed for different purposes. Conventional SDI systems were developed mostly for economic and environmental purposes. Following the recognition of the benefits from such SDI systems, a number of countries such as Australia, Canada and Japan are now building marine SDI as an extension to their successful national SDI. There are at present a number of specific purpose SDIs being developed or conceptualised such as the Arctic SDI and the Antarctic SDI. These were created to support scientific data management for scientific research in the Arctic and the Antarctic respectively. Similarly, other specifically developed SDIs include a Cultural Heritage SDI, Humanitarian SDI, Avalanche SDI, Laser Scanning SDI and the recently created Spatial Data Infrastructure for Development (SDI4MDGs). The SDI4MDGs is specifically developed for monitoring and achieving the Millennium Development goals, which relates to the goals established following the Millennium Summit of the United Nations in 2000 which aimed amongst other to eradicate poverty and to promote sustainable development (section, 2.4.6).

Developing an SDI system requires a lot of cooperation and effort between many parties. It is complex and dynamic and requires the commitment of example datasets, expertise, funds, technology and time. Thus, it is not unusual for many countries to face different kinds of problems in developing their spatial data infrastructure so much so that some countries have succeeded in implementing operational SDI systems, many others are still working to complete and implement their SDI and yet others have put development of their SDI on hold for a variety of

reasons. There are also countries in which SDI development has been postponed to allow for changes to reflect their particular needs.

The factors affecting the development of SDIs range from the problem of lack of digital and up-to-date spatial data (as in the case of African countries), lack of funding (as in the case of many transitional and developing countries), lack of internet and telecommunications facilities and electricity as in Nigeria and many other African countries to lack of political support such as in the case of many countries where poverty, food security, health-care (AIDs) and other social problems are their main priority.

1.2   Problem Statement

The development of Spatial Data Infrastructures has taken placed in more than 120 countries worldwide within the past two decades and Oman being one of the earliest countries to adopt the initiative, started the initiative way back in 1995.. The experience of many countries in developing their spatial data infrastructure has been shared at many conferences and in numerous published literatures. Although the Global Spatial Data Infrastructure (GSDI) association took the initiative to publish the SDI Cookbook (GSDI, 2009) to provide guidelines for the use of countries contemplating the development of their own SDI, it is just not sufficient for countries to merely follow the guidelines of the SDI Cookbook because different countries have different forms of governance, economic systems, societal values and culture, making any one country, and therefore their problems in SDI development, unique from the other countries. Thus, while the success factors of the exemplary operational SDIs are to be analysed and emulated, the factors impeding or contributing to the failure of the SDI development of any country (of which Oman is no exception) are to be thoroughly and adequately identified and analysed to enable the continued progress of the dynamic and complex SDI development till the achievement of an operational SDI.

1.3 Research Questions

This research was carried out by systematically observing the following research questions :

(i) What is a spatial data infrastructure and what does it consist of?

(ii) Which countries have successfully developed their spatial data infrastructure and why?

(iii) What are the factors that affect the development of a spatial data infrastructure?

(iv) What is the current situation of spatial data infrastructure in the Sultanate of Oman?

(v) What are the characteristics and types of spatial data used by the Geographic information (GI) communities in Oman?

(vi) What are the factors affecting or impeding the development of an Omani Spatial Data Infrastructure initiative?

1.4 Research Aim

The aim of this research is to identify the key barriers affecting the development of Oman Spatial Data Infrastructure so that appropriate solutions could be recommended to rectify the current problems in the development of the Oman SDI.

1.5 Research Objectives

The objectives of this research include the following:

(i) to study the nature and the development of a spatial data infrastructure.

(ii) to identify the key factors that affect the development of spatial data infrastructure.

(iii) to identify the factors impeding or inhibiting the development of Oman spatial data infrastructure.

(iv)   to recommend steps to be taken to enhance development of Oman spatial data infrastructure initiative.

1.6   Research Motivation

Oman is a developing country seeking to instigate Information Technologies (IT). The reason for this study is to contribute to directing effective implementation of SDI as part of the larger government initiative in promoting IT. By implementing SDI, Oman will be streamlining organisational decision making which will contribute to implementing IT and making Oman a more modern country.

1.7   Significance of the Research

It has been nearly twenty years since the National Survey Authority of Oman first initiated the idea in 1995 to adopt the development of a National Geographic Data Infrastructure (NGDI). While many countries in the world have successfully or partially successful in developing their national spatial data infrastructure within this time period, Oman does not make much progress and it is yet to see the development of the national SDI to materialise. Therefore, this study is important as it seeks to identify the factors which may contribute to Oman's failure and is significant to provide recommendation(s) to rectify the situation and to pave the way forward to a successful implementation of the NSDI.

1.8   Thesis Outline

The thesis is organised in five chapters as outlined below:

(i)   **Chapter 1**. The first chapter provides an introduction to the subject matter of the research and defines the research problem. It then identifies the aim of the research and the research questions which were addressed to solve the problem.

(ii) **Chapter 2.** The chapter outlines the scope of the spatial data infrastructure (SDI) and lists the various definitions of the SDI to indicate its complexity and dynamics. It also provides an overview of the development of SDI systems in other countries to show the various forms they can take and their wide scale acceptance by many countries in the world. Details on special purpose SDI systems are also included in this chapter.

(iii) **Chapter 3**. This chapter outlines the methods used to identify and describe the current situation in Oman and the user requirements.

(iv) **Chapter 4.** The chapter presents the result of the research relating to the most important factors identified to affect the development of SDI. These factors are compared to the findings relating to the development of the Oman SDI. It highlights the status of spatial data activities and provides a vision of the most important factors that impede the implementation of the Oman SDI.

(v) **Chapter 5**. The final chapter discusses relevant issues of the research in the context of improving the progress in the development of the Omani SDI and concludes with suggestions for future research.

REFERENCES

ADSIC, 2009. "Strengthening and Institutionalization Stage", Abu Dhabi Spatial Data Infrastructure System and Information (AD-SDI), *Advances AD-SDI Newsletter*, Issue 3, Quarter 3

AGI, 2009. UK GEMINI Standard, *Geo-spatial Metadata Interoperability Initiative, Version 2.0*

Ahmad Fauzi bin Nordin, 2006 . Topographic-Cadastral Data Integration issue: the Malaysian Case, proceeding *Seventeenth United Nations Regional Conference for Asia and the Pacific,* Bangkok, 18-22 September 2006

Akinyemi, F.O, 2007. Spatial Data Needs for Poverty Management, In: Onsrud,H.J. (ed.) *Research and Theory in Advancing SDI Concepts*, pp.262-277, ESRI Press, Redlands, USA

Al-Awadhi, T., 2002. GIS Implementation Strategy in Oman: Past, Present and Future, Geographic Department, Sultan Qaboos University, proceedings.esri.com

Al Bakri, M.M.S., 2012. *Developing tools and Models for Evaluating Geospatial Data Integration of Official and VGI Data Sources*, PhD Thesis, School of Civil Engineering and Geosciences, Newcastle University, United Kingdom, https//these.ncl.ac.uk

Al-Balushi, A., 2007. The Use of GIS National Survey Authority. *GIS conference*, Qatar, http://www.gisqatar.org.qa [accessed 20 March 2008]

Al Jabri, S., 2006. Electronic Archive in the Sultanate of Oman: the Experience of the Ministry of Housing*, Cybrarians Journal, No. 6,* March 2006, http://www.cybrarians.info /journal/no8/e-archive.htm , [accessed 20 May 2010]

Ali, S.H. and J.F. Shroder, 2011. *Afghanistan's Mineral Fortune: Multinational influence and development in a post-war economy*, Research Paper Series: C: 1:2011(1), Institute for Environmental Diplomacy and Security, University of Vermont, Burlington, Vermont, USA

ANZLIC, 2010 . Australia and New Zealand Spatial Information Council, http://www.anzlic.org.au, [accessed 5 May 2010]

Ara Toomanian, 2012. *Methods to Improve and Evaluate Spatial Data Infrastructure,* Centre for Geographical Information Systems, Lund University, Lund, http://lup.lub.lu.se, [accessed 22 May 2008]

Azaz, L. K., 2010. Using Remote Sensing and GIS For Damage Assessment After Flooding. The Case of Muscat, proceeding *Oman After Gonu Tropical Cyclone 2007*, Tagungsband, Vienna, 18-20 May 2010, Urban Planning Perspective, REAL CORP.

Bait-Ishaq, H and P. Burden, 1997. GIS Implementation in the Ministry of Water Resources in Oman, *Annual ESRI Middle East & Africa User Conference*, Qatar, 2002, http://www.gisqatar.org.qa [accessed 29 March 2008]

Baktah, P., 2003. National and Regional Spatial Data Infrastructure (NSDI & RSDI) and National Cartographic Center of Iran's Activities about it, proceedings *2nd FIG Regional Conference*, Marrakech, Morocco, 2-5 December 2003

Barr, R., 1998. "I had a dream....?, *GIS Europe*, pg. 16-17, December 1998

Bartoli, F. and C.M. Medaglia, 2012. GeoAvalanche - Spatial Data Infrastructure for Avalanche Awareness Warning, *FIG Working Week 2012,* http:www.fig.net, [accessed 6 March 2013]

Borgman, C.L., and M. Krasny, 2000. *From Gutenberg to the Global Information Infrastructure: Access to Information in the Networked World,* MIT Press, Cambridge, MA

Bowker, G.C., K. Baker, F. Millerand and D. Ribes, 2010. Toward Information Infrastructure Studies: Way of Knowing in a Networked Environment, *International Handbook of Internet Research*, pp. 97-117, Springer, Netherlands

Bregt, A. and J. Crompvoets, 2005. Spatial Data Infrastructures: Hype or Hit? From Pharaohs to Geomatics, *FIG Working Week 2005 and GSDI-8*, 16-21 April 2005, Cairo, Egypt, http: //www.fig.net

Cai,G., 2002. A GIS approach to the spatial assessment of telecommunications infrastructure, *Networks and Spatial Economics*, 2 (1), pp. 35-63

Chan, T.O., M.E.F. Feeny, A. Rajabifard and I. Williamson, 2001. A method of descriptive classification, Geomatica, 55(1), pp.66-72

Casado, M. L., 2006. Some basic mathematical constraints for the geometric conflation problem, *7th International Symposium on Spatial Accuracy Assessment in Natural Resources and Environmental Sciences*, Lisbon, Portugal, pp. 264-274

CGDI, 2008. Canadian Geospatial Data Infrastructure, http://www.geoconnections.org [accessed 5 August 2008]

Chan, M.E.Freeney, A.Rajabifard and I.P. Williamson, 2001. *The Dynamic Nature of SDIs,* A method of Descriptive Classification, Department of Natural Resources and Environment, East Melbourne, Victoria.

Chris Parker, 1997. GIS and Environmental Management in the Sultanate of Oman, http://www.gisqatar.org.qa [accessed 18 March 2008]

Clausen, C. A. Rajabifard, S. Enemark and I. Williamson, 2006. Awareness as a Foundation for Developing Efficient Spatial Data Infrastructures, *XXIII FIG Congress*, 8-13 October 2006, Munich, Germany

Colless, R., 2005. Interoperability and Security In The Emergency Services Arena. http://www.anzlic.org.au, [accessed 15 May 2009]

Craglia, M. 2010 .Building INSPIRE: The Spatial Data Infrastructure for Europe, ESRI Understanding our world, *ArcNews Online*, http://www.esri.com [accessed19 June 2012]

Craglia, M. and A. Annoni, 2007. INSPIRE: An Innovative Approach in the Development of SDIs in Europe, pp. 93- 105, In: Onstrud, H.J., *Research and Theory in Advancing Spatial Data Infrastructure Concepts,* ESRI Press, Redlands, USA

Crompvoets, J. and A. Bregt, 2003. World Status Of National Spatial Data Clearinghouses, *URISA Journal* 15, pp. 43-50, www.researchgate.net [accessed 15 March 2013]

Crompvoets, J., A. Bregt, A. Rajabifard and I. Williamson, 2004. Assessing the Worldwide Developments of National Spatial Data Clearinghouses, *International Journal of Geographical Information Science*, vol. 18 (7), pp. 665-689, Taylor and Francis

Crompvoets, J., 2006. *National Spatial Data Clearinghouses Worldwide Development and Impact,* PhD Thesis, Wageningen University, Wageningen, Netherlands

Crompvoets, J., A. Rajabifard, B. van Lonen and T.D. Fernandez (eds.), 2008. *A Multi-view Framework to Assess Spatial Data Infrastructures,* Space for Geo-Information (RGI), Wageningen University, Netherlands.

Dalrymple, K., I. Williamson, and J. Wallace, 2003, Cadastral Systems within Australia, *Australian Surveyor*, vol. 48(1), pp. 37-49. Taylor and Francis

Davis, C.A. and F. Fonseca, 2006. Considerations from the Development of a Local Spatial Data Infrastructure, *Information Technology for Development*, vol. 12 (4), pp. 273-290

Donker, F.W. and B. van Loenen, 2006. Transparency of accessibility to government-owned geoinformation, *12th EC-GI &GIS Workshop,*Innsbruck, Austria, page 1-12, Citeseer.

Drexhage, J. and D. Murphy, 2010. Sustainable Development:From Brundtland to Rio2012,*background paper, High Level Panel on Global Sustainability,* 19 September 2010, United Nations, New York, www.popline.org

Duffy, T. (ed.), 2010. Creating Scotland's Spatial Data Infrastructure. Cookbook 1: *How to serve a Scottish SDI and INSPIRE Conformant Web Map Services,* British Geological Survey. NERC 2010, UK

Edward, D. and J. Simpson, 2002. Integration and access of multi-source vector data, *Symposium on Geospatial Theory, Processing and Applications,* Ottawa, Canada, pp.1-8

Eelderink, L., 2006. *Towards key variables to assess National Spatial Data Infrastructures (NSDIs) in developing countries*, Geographical Information Management and Applications (GIMA), http://www.itc.nl, [accessed 27 July 2011]

ESCWA, 2007. *National Profile for the Information Society in the Sultanate of Oman*, United Nations, www.escwa,un.org, [accessed 22 February 2002]

Fernandez,T.D., 2008. The Spatial Data Infrastructure Readiness model and its worldwide application, In: Crompvoets, J., A. Rajabifard, B. van Lonen and T.D. Fernandez (eds.), 2008. *A Multi-view Framework to Assess Spatial Data Infrastructures*, pp. 117-134, Space for Geo-Information (RGI), Wageningen University, Netherlands.

FGDC, 1996. The National Spatial Data Infrastructure, http://www.fgdc.gov, [Accessed 10 October 2011]

FGDC, 2010. Federal Geographic Data Committee Steering Committee Charter, http://www.fgdc.gov. [accessed 13 June 2010]

Finn, M.P., L. Usery, M. Starbuck, B.Weaver, and G.M. Jaromack, 2004. Integration of the national map, *XXth Congress of the International Society of Photogrammetry and Remote Sensing, Istanbul, Turkey*, p. 1-3

FRC, 2007. Future requirements committee report (unpublished document), National Survey Authority.

GeoConnections, 2004. *A Developers Guide to the CGDI: Developing and Publishing geographic information, data, and associated services*, Ottawa, Ontario, Canada.

GSDI, 2014. Global Spatial Data Infrastructure Association-Advancing a Location Enabled World, *GSDI and IGS Global News*, vol. 4(1), 2014

GSDI, 2009. *Spatial Data Infrastructure Cookbook 2009*, www.gsdi.org, [accessed October 9, 2012]

Hadley, C. and L. Elliott, 2002 . National Geospatial Data Framework (NGDF) – The UK Model. *GIS Development*, http://www.gisdevelopment.net, [accessed 21 May 2010]

Hanseth, O. and K. Lyytinen, 2010. Design Theory for Dynamic Complexity in Information Infrastructures: The Case of Building Internet, *Journal of Information Technology*, vol 25, pp 1–19.

Hansen, H.S., L. Schrøder, L. Hvingel and J. Skovdal, 2011. Towards Spatially Enabled e-Governance – A Case Study on SDI implementation, *International Journal of Spatial Data Infrastructures Research,*Vol. 6, pp. 73-96. http://ijsdir.jrc.ec.europa.eu, [accessed 14 March 2012]

Heinbockel, R., F.H. Al-Kindy, F. Zhu, H. Friesacher and S. Hatmiy, 2008. Gravity and magnetic data management in PDO; How it made a difference!, *EAGE Workshop Non Seismic Methods*, Manama, Bahrain 12-15 October 2008

Hocking, D., 2010. In-Vehicle Telematics: Informing a National Strategy, *discussion paper submitted by Spatial Industries Business Association,* http://www.pc.gov.au, [accessed 10 disember 2012]

Hofle, B., N. Pfeifer and A. Zipf, 2011. Laser Scanning Spatial Data Infrastructure (LaSDI), *The European Science Foundation exploratory workshop*, September 9 – 10, 2011, www.geog.uni-heidelberg, [accessed 4 May 2012]

ITHACA, 2012. *About ITHACA. A Joint Project with World Food Programme*, http://www.ithacaweb.org/about [accessed 15 May 2012]

Kay, S.,1988. Geographic Information Systems: An integrated database for Badiyah, In: Dutton, R.W. (ed.) The Scientific Results of the Royal Geographical Society's Oman, Wahaiba Sands Project 1985 - 1987, *The Journal of Oman Studies* Special Report Number 3,pp.47-54, Office of the Adviser for Conservation of the Environment, Muscat, Sultanate of Oman.

Khalid A. Rahman, 2013. Building a NSDI to support Bahrain National Geospatial development, *UN-GGIM* , Doha, Qatar February 2013, www.ggim.un.org.

Klinkenberg, B., 2003. The true cost of spatial data in Canada, *The Canadian Cartographer,* vol.47(1), pp. 37-49, Wiley Online Library, www.onlinelibrary.wiley.com

Krolikowski, M., 2007. Subsurface Geological Data and their Integrated in ArcGIS, *ESRI Middle East & North Africa User Conference* , Oman 29-31- October 2007, http://www.meauc.com, [accessed 19 May 2010]

Lance, K., 2003. Spatial data infrastructure in Africa: spotting the elephant behind trees, www.academia.edu [accessed 22 September 2013]

Maguire, D.J. and Longley, P.A., 2005.The emergence of geoportals and their role in spatial data infrastructures', *Computers, Environment and Urban Systems*, 29: 3–14.

Maitra, J.B., 2002. The National Spatial Data Infrastructure in the United States: Standards, Metadata, Clearinghouse, and Data Access , *GIS development electronic magazine,* Federal Geographic Data Committee, http://www.gisdevelopment.net, [accessed 13 June 2010]

Mansourian, A. and M.J. Zoej, 2008. Expanding SDI Hierarchy for Countries with Non-federated System: A Case Study of Iran. *World Applied Sciences Journal* 3 (4), IDOSI Publications

Manisa, M. and Nkwae, B., 2007. Developing Botswana Spatial Data Infrastructure: From Concept to Reality, Spatial Data Infrastructures. *Strategic Integration of Surveying Services, FIG Working Week 2007*. Hong Kong SAR, China, 13-17 May 2007

Masó, J., X. Pons and A. Zabala, 2012 .Tuning the second-generation SDI: theoretical aspects and real use cases. *International Journal of Geographical Information Science, vol.* 26(6)

Masser,I.,1998.*Governments and Geographic Information*, Taylor & Francis, London

Masser, I.,1999. All Shapes and Sizes: The First Generation of National Spatial Data Infrastructures, *International Journal of Geographical Information Science,* 3, pp. 67-84.

Masser, I., 2002. *Report on A comparative analysis of NSDI's in Australia, Canada And the United States*, Geographic Information Network in Europe, www.ec-gis.org, [accessed 12 April 2012]

Masser, I., 2005a. *GIS Worlds - Creating Spatial data Infrastructures*, ESRI Press, Redlands, CA.

Masser, I., 2005b. The Future of Spatial Data Infrastructures, *ISPRS Workshop on Service and Application of Spatial Data Infrastructure, XXXVI (4/W6)*, 14-16 October 2005, Hangzhou, China

McDougall, K., 2010. From Silos to Networks – Will Users Drive Spatial Data Infrastructures in the Future?, *FIG Congress 2010 Facing the Challenges – Building the Capacity* ,Sydney, Australia, 11-16 April 2010 http://eprints.usq.edu.au

McDougall, K., A. Rajabifard and I. Williamson, 2007. A Mixed-Method Approach for Evaluating Spatial Data Sharing Partnerships for Spatial Data Infrastructure. In:Onsrud, H. (ed.), *Research and Theory in Advancing Spatial Data Infrastructure Concepts,* pp. 33-54. Redlands, CA: ESRI Press

Mohammadi, H., 2008. *The Integration of Multi-source Spatial Datasets in the Context of SDI Initiatives*. PhD thesis, University of Melbourne. Australia.

MONE, 2006. *Socio_Economic Atlas*. September 2006, pp. 2-8, Ministry of National Economy

MOTC, 2010. Ministry of transport and communication, http://www.motc.gov.om [accessed 12 October 2010]

Murakami, H., 2008. Japanese Legislate to Advance Geo-information. *GIM International* Mapping the world, Vol. 22 (2), February 2008, http://www.gim-international.com,

Muto, M., 2009. Developing the Marine Information System for Ocean Governance: Towards the Development of Japanese Marine Cadastre, *The SUIRO*, 150, pp. 27-33.

MyGDI, 2010. About MyGDI, Malaysia Geoportal, www.mygeoportal.gov.my, [accessed on 22 may 2010]

Najar,C., A.Rajabifard, I.Williamson , C.Giger, 2006. A Framework for Comparing Spatial Data Infrastructures. An Australian-Swiss Case Study. *GSDI-9 Conference* proceedings, 6-10 November 2006, Santiago, Chile, pp.10-18

Nebert, D., (ed.), 2004. *Developing Spatial Data Infrastructures The SDI Cookbook.* Version 2.0 Online, http://www.gsdi.org [accessed 25 January 2012]

Nebert, D., 2009. *Spatial Data Infrastructure: Concepts and Components*, U.S. Federal Geographic Data Committee, http://www.fgdc.gov [accessed 11May 2013]

Nichols, S., D.J. Coleman, and K. Saylam*, 1999 .Towards A Conceptual Framework Architecture to Support the Canadian Geospatial Data Infrastructure (CGDI) .*A Report for the GeoConnections Secretariat, www.geos.ed.ac.uk [accessed 7 May 2011]

Nkambwe, M., 2002. Land information Systems Development and the National Spatial Data Infrastructure in Botswana. *ISPRS Commission VI Workshop - Developments and Technology Transfer in Geomatics for Environmental and Resource Management*. 25-28 March 2002. Dar es Salaam, Tanzania

Nkwae, B. and S. Nichols, 2002. Spatial Data Infrastructures: African Experiences. *FIG XXII International Congress*, Washington D.C, USA *FIG*

NSA, 2003. *Combined Specification for the production of 1:50,000 and 100,000 National Mapping,* edition 1, National Survey Authority, Ministry of Defence, Sultanate of Oman

NSA, 2013. National Survey Authority website, http://www.mod.gov.om, [accessed 21 January 2013]

OER, 2014. Oman Economic Reviewer, http://www.oeronline.com [accessed 3 March 2014]

O'Flaherty, B., E. Hayes, G. Kiely and D. Bartlet, 2006. The Dynamics of a Spatial Data Infrastructure – A National Case Study, 01/2006; proceedings of the *Fourteenth European Conference on Information Systems, ECIS* 2006, Göteborg, Sweden, 2006, http://is2.lse.ac.uk [accessed 30 March 2010]

O'Sullivan, M. J., 2004. Political and Implementation Challenges of Integrating Land Information into a Coherent Land Administration System for Sustainable Development. *UN, FIG, PC IDEA Inter-regional Special Forum on the Building of Land Information Policies in the Americas Aguascalientes*, Mexico 26-27 October 2004

Onah, C.C., 2009. *Spatial data Infrastructures Model for Developing Countries: A case study of Nigeria.* MSc Dissertation. James I University. Spain, http://run.unl.pt [accessed 11 December 2010]

Ono, A., 2009. Overview of the Japan Spatial Data Infrastructure, i.csis.u-tokyo.ac.jp [accessed 29 November 2013]

Onsrud,H. (ed.), 2007. *Research and Theory in Advancing Spatial Data Infrastructure Concepts*, ESRI Press, Redlands, California.

Omran, E.- S.E., 2007. *Spatial Data Sharing: From Theory to Practice*., PhD thesis, Wageningen University, Wageningen The Netherlands

Omtzigt,N., N. de Reus, E. Koomen and A. Arezza, 2008. The Construction of a Spatial Data Infrastructure for Cultural Heritage, In: Cunningham, P. and M. Cunningham (eds.), 2008. *Collaboration and the Knowledge Economy: Issues, Applications, Case Studies.* Amsterdam, IOS Press, pp. 1366–1373

PCDESR,1993. *Khawrs and Springs of the Dhofar Governorate. Survey and Monitoring Studies*; Planning Committee for Development and Environment in the Governorate of Dhofar, Salalah, Sultanate of Oman

Pironti, J.P., 2006. Key Elements of a Threat and Vulnerability Management Program, *Information Systems Audit and Control Association Member Journal*, pp 1-5.

Rackham, L. and D. Rhind, 1998. Establishing the UK national data framework. *SDI'98*, Ottowa, Canada

Rajabifard, A., M.E.F. Feeney, I. Williamson and I. Masser, 2003. *Chapter Six National Sdi-Initiatives.* In: Williamson, I., A. Rajabifard and M. E. F. Feeney, 2003. Developing Spatial Data Infrastructures: From Concept To Reality, Taylor & Francis, London, pp. 95–109

Rajabifard, A., I. P. Williamson, P. Holland, and G. Johnstone, 2000, From Local to Global SDI Initiatives: a pyramid building blocks, *Proceedings of the 4th GSDI Conference,* Cape Town, South Africa

Rajabifard, A., 2009. Realizing Spatially Enabled Societies – A Global Perspective in Response to Millennium Development Goals, *18th UNRCC-AP Conference*, 26-30 October 2009, Bangkok, Thailand http://unstats.un.org

Rhind, D.W., N.P., Green, H.M. Mounsey and J.S. Wiggins, 1984. The Integration of geographical data*, Proceedings of Austra Carto Perth, Australian Cartographic Association.* pp. 273-293.

RNO, 2013. Royal Navy of Oman, http://rno.gov.om

Robinson, M., 2008, *A History of Spatial Data Coordination*, http://www.fgdc.gov, [accessed 14 June 2012]

Russell, I., 2009. What is Marine SDI? Southern Region Autumn Symposium 2009, Hydrographic Society United Kingdom, www.ths.org.uk [accessed 14 August 2013]

Ryttersgaard, J., 2001. Spatial Data Infrastructure-Developing Trends and Challenges, *International Conference On Spatial Information For Sustainable Development*, Nairobi, 2-5 October 2001

Salvemini,M., F. Vico and C. Iannucci, 2011. *Interoperability for Spatial Planning*, Plan4all Project, Brussels, Belgium

Sebake, M.D. and S. Coetzee, 2013. Address Data Sharing: Organizational Motivators and Barriers and their Implications for the South African Spatial Data Infrastructure, *International Journal of Spatial Data Infrastructures Research*, 2013, Vol.8, 1-20

Schmid, G., 2003.Towards a common geographic information framework for England, pp. 2-8, www.knowledge.co.uk, [accessed 5 November 2011]

Schrenk, M., J. Neuschmid, O. Rathschüler and S. Kollarits, 2012. Development of a Planning Information System to Support Environmental Planning in the Sultanate of Oman, Frame of the Oman National Spatial Strategy, *48th ISOCARP Congress 2012*, http://www.isocarp.net [accessed 4 June 2013]

SCTP, 2008. OMAN TENDER: National Spatial Strategy Consultancy Services, *MEED*, 15 October 2008, http://www.meed.com [accessed 22 July 2013]

Singh, P. K., 2009. Spatial Data Infrastructure in India: Status, Governance Challenges, and Strategies for Effective Functioning, *International Journal of Spatial Data Infrastructure Research*, vol. 4, pp. 359-388

Sinton, D.F., 1978. The inherent structure of information as a constraint to analysis: Mapped thematic data as a case study. In: Dutton, G. (ed)., 1978. Harvard papers on geographic information systems, 6, pp.1-17, http://scholar.google.com .

Snoeren, G., S. Zlatanova, J. Crompvoets, and H. Scholten, 2007. Spatial Data Infrastructure for Emergency Management: The View Of The Users. proceedings of *the 3rd International symposium on Gi4DM,* Toronto, Canada, 22–25 May 2007

Smit, J. and P. Makanga, 2010. A Review the Status of Spatial Data Infrastructure Implementation in Africa. *South Africa Computer Journal*, No. 45, July 2010

Sorensen, M. 2006. *Workshop Statement and ASDI Road Forward. Final Draft,* Afghanistan Central Statistics Office and Afghanistan Geodesy and Cartography Head Office, USGS and USAID, *1st Afghanistan Spatial Data Infrastructure Workshop*,17-19 July 2006

Spatial Dimension, 2012. Tanzania Online Mining Cadastre Portal Launched, *Asian Surveying & Mapping*, 27 September 2012, https://www.asmmag.com

Spatial Dimension, 2013. Design and Implementation of a Mining Cadastre (Mineral Rights Management System), http://spatialdimension.com [accessed 15 Jun 2013]

Subsea, 2013. IHO Marine Spatial Data Infrastructure Meetings Take Place in Denmark, *Subsea World News*, http://subseaworldnews.com [accessed 30 June 2013]

Thellufsen, C. B., A. Rajabifard, S. Enemark, and I. Williamson, 2009. Awareness as a foundation developing effective spatial data infrastructures, *Land Use Policy* 26(2), pp. 254-261

Travers Morgan, 1996. *Detailed Land Use Study in Jabal Dhofar, Phase I Final Report, Survey of Current Conditions*, Supreme Committee for Town Planning, Muscat, Sultanate of Oman.

Uitermark, H.T., 2001. *Ontology-Based Geographic Data Set Integration*, Thesis Twente University, Deventer, the Netherlands, http://doc.utwente.nl [accessed 25 June 2013]

Uitermark,H.T. C. Dutch, and Apeldoorn 1996. The integration of geographic databases: realizing geodata interoperability through the hypermap metaphor and a mediator architecture*, Proceedings of the Second Joint European Conference and Exhibition on Geographical Information,* Barcelona, Spain, IOS Press, pp. 92-95.

UNDP, 2014. Millennium Development Goals: What they are, http://www.unmillenniumproject.org , [accessed 11 April 2014]

UN,1992. AGENDA 21, United Nations Conference on Environment and Development, Rio de Janerio, Brazil, 3-14 June 1992, United Nations Sustainable Development, http://sustainabledevelopment.un.org

USA, 1994. *Executive Order 12906* . Vol. 59 (71), Presidential Documents, United States of America

Usery, E.L., M.P. Finn and M. Starbuck, 2005. Integrating data layers support the national map of the United States*, International Cartographic Conference,* A Corua, Spain, pp. 5

USGS, 2011. *U.S. Geological Survey* website, http://www.usgs.gov. [accessed 3 May 2011]

Vancauwenberghe, G., J. Crompovoets, G. Bouckaert and D. Vandenbroucke, 2009. A network Perspective on Spatial Data Infrastructure: SDI as support to e-government. *GSDI11*, 15-19 June 2009. Rotterdam, the Netherlands.

Vandenbroucke, D., J. Crompvoets, G. Vancauwenberghe, E. Dessers and J. van Orshoven,2009, A Network Perspective on Spatial Data Infrastructures: Application to the Sub-national SDI of Flanders (Belgium). *Transactions in GIS*, 13(1), pp. 105-22

van Loenen, B. and E. van Rij, 2008. Assessment of Spatial Data Infrastructures from an organizational perspective, In: Crompvoets, J., A. Rajabifard, B. van Loenen, and T. D. Fernández (eds.), 2008. *A multi-view framework to assess spatial data infrastructures*, pp. 173-192.

Vandenbrouke, D. and D. Biliouris, 2010. Spatial Data Infrastructures in The United Kingdom: State of play 2010, K.U.Leuven

Vasdev, S., 2011. Feasibility Study for a National Spatial Data Infrastructure in Jordan. *InfoDev Growing Innovation*, http://www.infodev.org [accessed 21 Jan 2013]

Vogt, S. 2005. AntSDI: The Coolest SDI on Earth? - Towards a Spatial Data Infrastructure for Antarctica, *FIG Working Week 2005 and GSDI-8*, Cairo, Egypt April 16-21, 2005, https://www.fig.net

Warnest, M., 2005. *A collaboration model for national spatial data infrastructure in federated countrie*s, University of Melbourne, Australia.

Weaver, B., 2004. *Implementing of the national map road database,* Nashville, Tennessee, the United States of America

Williamson,I., A. Rajabifard and M.E.F. Feeney, 2003, *Developing Spatial Data Infrastructures: From Concept to Reality*, Taylor and Francis, London, New York

Williamson,I., D. G. Grant, and A. Rajabifard, 2005. Land administration and spatial data infrastructures. *GSDI-8 Conference*. Cairo, Egypt.

Yang, K., J. Chen and W. Wu, 2013. Recent progress in China's NSDI Development, www.sbsm.goc.cn [accessed 18 October 2013]

Young, C., 2013. Zambia and Kenya publish their mining cadastre data online. GOXI Sharing in Governance of Extractive Industries, February 4, 2013.

Zeiss, 2012. *Denmark's open data initiative estimated to save government over $45million per year and generate returns of $87 million for the private sector.* Between the Poles, http://geospatial.blogs.com [accessed May 2013]