St Clements University

INVESTIGATING THE EFFECTIVENESS OF GIS-BASED ANALYSIS TOWARDS THE COORDINATION OF HUMANITARIAN ASSISTANCE IN YEMEN

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By

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This thesis is submitted in partial fulfillment of the requirements for the Degree of

Doctor of Philosophy in Information Technology

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BRITISH WEST INDIES

Dissertation directed by

Dr. Adnan Al-Saqaff
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Dedication

I dedicate my thesis work to my family and many friends. A special feeling of gratitude to my loving mother and father whose words of encouragement and push for tenacity ring in my ears.

My beloved wife never left my side and always very supportive.

I also dedicate this thesis to my kids, my brothers, sisters and best friends.

I also dedicate this work to my beloved country Yemen.

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الملخص باللغة العربية

انطلاقا من ايمان الباحث بأهمية العلم و العمل من أجل الوطن و المجتمع و نظرا للوضع الانساني المتأزم في اليمن و طبيعة تخصص الباحث في مجال تقنية المعلومات و استنادا الى الخبرة العملية في مجال العمل الانساني مع مكتب تنسيق الشئون الانسانية في الامم المتحدة في اليمن فقد رأى الباحث ان يكون مغزى و هدف هذه الاطروحة إيضاح أهمية استخدام تقنيات المعلومات بشكل عام و نظام المعلومات الجغرافية بشكل خاص في دعم اتخاذ القرارات علي جميع المستويات الانسانية و الاقتصادية و الاجتماعية وحتى السياسية و بالتالي فان هذه الاطروحة تدرس التحقق من فعالية ادوات تحليل نظام المعلومات الجغرافية في تنسيق المساعدات الانسانية في اليمن

تواجه اليمن حالة من الطوارئ المعقدة تشمل نزوح منتشر بسبب الصراع وبداية أزمة بطيئة في الأمن الغذائي وسوء التغذية وتفشي الأمراض السارية خاصة الأمراض التي تنتقل عن طريق الماء كما تسببت الاضطرابات المدنية التي صاحبها في بعض الحالات أعمال عنف شديدة في تعطيل وصول الخدمات الاجتماعية الأساسية مما أدى إلى تفاقم الفئات الضعيفة المزمنة والمنتشرة. حيث تسبب النمو الاقتصادي الضعيف ونمو العجز التجاري وعدم استقرار قيمة العملة الوطنية إلى ارتفاع عالمي لأسعار الوقود والمواد الغذائية.

و من واقع خبرة الباحث العملية فان تقديم المساعدات الإنسانية إلى المحتاجين صعب جدا ومعقدة بسبب نقص المعلومات وعدم استقرار الوضع الأمني في معظم المناطق الجغرافية اليمنية.

وبالرغم من توافر بعض المعلومات الجغرافية ومعلومات السكان والصحة والتعليم فان مشكلة اتخاذ قرار خاص بتقديم المساعدات الانسانية لا تزال صعبة بالنسبة للحكومة ووكالات الأمم المتحدة ومنظمات المجتمع المدني .

كما يمثل وضع الاستخدام النادر لتقنية المعلومات و أدوات تحليل البيانات و المعلومات واحدة من عقبات التنسيق والمساعدة الإنسانية في اليمن.

ان الهدف من هذه الأطروحة هو التحقق من فعالية ادوات تحليل نظم المعلومات الجغرافية في تنسيق المساعدات الانسانية في اليمن و ذلك خلال الازمة الانسانية التي اعلنت عنها الامم المتحدة وذلك عبر بناء طريقة استكشافية خاصة مكونة من خمس مراحل تلبي الغرض من هذه الاطروحة و هذه المراحل تبدا بجمع البيانات و معالجتها و من ثم مرحلة البناء و التنفيذ للأليات و البرمجيات و يأتي بعد ذلك مرحلتي التأكد و الدعم لتصورات الباحث و اسئلة الاطروحة و هما عبارة عن مرحلة البحث النوعي و البحث الكمي و بعد ذلك تأتي المرحلة الاخيرة بالاستنتاجات و الخلاصة و التوصيات و يمكن استخدام هذه الطريقة في بلد اخر حسب معطيات البيانات

و خرجت هذه الدراسة او الاطروحة بالإجابات على السؤال الرئيسي للبحث (<u>هل التحليل المبني على اسس نظم المعلومات الجغرافية يمكن أن يكون له تأثير حاسم على تنسيق المساعدات الإنسانية؟</u>) و كذلك الاسئلة الفرعية و بحيث اكدت الاجابات على انه فعلا ان تحليل نظم المعلومات الجغرافية لها تأثير حاسم و فعال في تنسيق المساعدات الانسانية في اليمن .

Abstract of Thesis

Investigating the Effectiveness of GIS-Based Analysis towards the Coordination of Humanitarian Assistance in Yemen

This thesis investigated if Geographic Information Systems (GIS)-based analysis can have a decisive influence upon the coordination of international humanitarian assistance in Yemen. Utility was assessed through five-phase sequential exploratory mixed methods approach and series of case studies demonstrating the application of GIS-based analysis to facilitate coordination of recent or potential humanitarian interventions. Some major categories of analysis were investigated: queries and measurement, transformation, optimization, geostatistics, geovisualization and hypothesis testing and simulation. The researcher adopted the sequential exploratory method (i.e. mixed method) approach, which involved data collection, implementation and qualitative and quantitative research phases designed to elicit the opinion of humanitarian professionals from around Yemen. This statistically-representative sample population was then used to test a set of research questions. Based upon the quantitative results, it was possible to conclude that GIS-based analysis *can have* a decisive impact upon the coordination of humanitarian assistance. GIS appears to offer substantial utility beyond its cartographic applications, particularly for applications such as Site Selection, Geovisualization, Vulnerability Estimation, Cluster Analysis and Range Analysis. This *utility* assessment, while very encouraging, does not necessarily demonstrate the *feasibility* of GIS-based analysis.

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Chapter 1 - Introduction

1.1 Statement of Problem

Yemen is facing a complex emergency that includes widespread conflict-driven displacement and a slow-onset crisis in food security, malnutrition and outbreak of communicable diseases, particularly water-borne diseases. In the north, the vast majority of long-term internally displaced people (IDPs) displaced by six rounds of conflict in Sa'ada remain in displacement due to fears of insecurity, damaged homes, a lack of livelihood opportunities and poor basic services. In the south, recent fighting between security forces and insurgents has additionally displaced nearly 90,000 people. The influx of migrants, refugees and asylum-seekers from the Horn of Africa continues, driven by conflict and famine. Civil unrest, in some instances involving high levels of violence, has severely disrupted the delivery of basic social services, exacerbating widespread and chronic vulnerabilities. Weak economic growth, a growing trade deficit, and an unstable national currency have exposed the population to rising global food and fuel prices. A delayed political settlement to the current stalemate could trigger further conflict across the country which would only deepen the humanitarian crisis.

United Nation Office for Coordination of Humanitarian Affairs started to operate in Yemen after Hadrmout floods in 2009, and since the researcher joint OCHA in the beginning of 2010, he noticed the difficulties and the obstacles of providing effective humanitarian coordination between all humanitarian actors in Yemen.

Delivering the humanitarian assistance to people in need was very difficult and complicated because of lacking the information and instability of the security situation in most of geographical areas of Yemen.

Despite the availability of some geographical, population , health or education information , still difficult for government , UN Agencies and Non-Governmental Organization to provide effective decision about the way of distribution necessary aid to people in need.

Also the rare use of Information Technology Tools and analysis is one of the obstacles of coordination the humanitarian assistance.

More than any other Geographic Information Systems (GIS) user group, the humanitarian sector appears to be the least progressive in exploiting the analytical potential of GIS technology. Insufficient financial and technical capacity is the most convenient explanation of why very few humanitarian organizations depend upon GIS beyond basic cartographic applications. But perhaps the reluctance to invest in advanced GIS programs is actually due to the failure of advocates to produce compelling evidence that GIS-based analysis can provide pragmatic, sustainable benefits to humanitarian organizations. The tentative approach observed to date is likely to continue until the much-heralded applications of GIS are satisfactorily demonstrated, and then accepted as “best practices” by the humanitarian community-at-large.

Even the United Nations (UN) has struggled to enjoy the full potential of GIS, despite significant institutional commitment. In the Mission Review of the

UN Office for the Coordination of Humanitarian Affairs (OCHA) in Yemen and Information Management Working Group (IMWG) members concluded that three years and many deployments in Yemen, analysis of information to support strategic and operational decision-making by OCHA remains "unresolved". [2, p.3]

These observations are symptomatic of a community not sure of just how useful GIS-based analysis is for humanitarian assistance. There is a dearth of research in this particular area of GIS, and much of what does exist is, in fact, a sub-set of GIS research for users of other applications, such as defense, public health, transportation, or homeland security. There are few objective analyses of humanitarian applications of GIS in the literature, and most journal articles and conference papers lack the scientific rigor necessary to make any conclusions about the overall utility of GIS-based analysis for supporting decision making in humanitarian assistance.

1.2 Research Goal

The research goal of this thesis is to investigate the effectiveness of GIS-based analysis to support the coordination of humanitarian assistance during UN-declared Humanitarian crisis in Yemen. Through applying and studying a method combine the information technology concept with the concept of GIS based analysis. Because the current use of GIS for this application is immature, the research goal includes an assessment of speculative *as well as* proven utility of each principle type of analysis, using realistic scenarios based upon recent humanitarian interventions by the UN.

1.3 Theoretical Context Diagram

Figure 1.1 illustrates how the above research goal coincides with the theoretical context. The darker boxes indicate the focus areas of the thesis, and the lighter boxes acknowledge peripheral areas which were relevant to, but not the thrust of this thesis. Humanitarian clusters are an evolving paradigm first tested during the response to the October 8, 2005, South Asian earthquake, and refined during more recent UN deployments such as the Yemen armored conflict during since 2006. The global lead agencies appointed for each cluster in that emergency are listed in parenthesis for reference – each cluster experience typically involves a unique formulation of cluster lead agencies.

Figure 1.1 Theoretical Context Diagram

Humanitarian Clusters

Cluster Coordination (UN OCHA)
Camp Management /Emergency Shelter (UNHCR)
Early Recovery (UNDP)
Education (UNICEF)
Health (WHO)
Food (WFP)
Nutrition (UNICEF)
Protection (UNHCR)
Water & Sanitation (UNICEF)

GIS Phenomena

Queries & Measurements
Transformations
Optimization
Statistical Analysis
Geovisualization
Hypothesis Testing & Simulation
Remote Sensing & GPS
Data Availability & Collection
Information Sharing
Data Models
Geospatial & Humanitarian Standards
Web-based GIS
Education, Research & Training
Map Templates &Symbology

1.4 Purpose

The purpose of this thesis is mainly to support better humanitarian coordination between different humanitarian actors in Yemen which lead to the following:

1. Better mechanisms of aid distribution.
2. Encouraging of information sharing between the agencies.
3. More beneficiaries.
4. Mobilize resources.
5. Effectiveness of humanitarian assistance and projects.
6. Promote the use of the technology and analysis tools for decisions makers.

During the process of thesis the researcher will mainly study the speculative utility of GIS-based analysis, and its ability to have a decisive impact the coordination of humanitarian assistance in Yemen according to various vectors and variables. Since there is little operational experience in the types of analysis discussed, the main purpose of this thesis is to identify those applications which have the greatest *potential* usefulness. No attempt is made to assess *feasibility* of GIS-based analysis, although the first phase of this thesis does identify the most pragmatic opportunities to exploit various types of GIS-based analysis. (Feasibility, in most cases, is better assessed by the organizations intending to conduct the analysis rather than by a third-party, since it requires intimate knowledge of analytical priorities, user sophistication, data availability, and technical proficiency.)

1.5 Significance

This thesis is significant for several reasons.

1. The humanitarian situation in Yemen is in a continues to deterioration and there is a lot of obstacles facing the provision of Humanitarian assistance in all geographical areas of Yemen (for example lack of significant information, bad planning, absent of right analysis tools), so this thesis in my opinion can at least help to have a better decision making in terms of humanitarian coordination mechanism and provision.

2. This is the first thesis in Yemen try to connect the use of Geographical Information systems as an Information Technology tool to support the humanitarian assistance and at the same rise the awareness of advanced information technologies and its analysis

tools

3. It offers an original method with which to assess the utility of GIS-based analysis amongst a community of potential beneficiaries
4. It provides a user-centric evaluation of the utility of incorporating GIS analysis into humanitarian assistance – this is particularly unique and exciting since the GIS needs of the humanitarian community do not appear to have been formally and scientifically assessed using actual case studies
5. This research contrasts the theoretical versus applied practices in GIS analysis, and answers the often-asked question, "a lot of GIS applications are theoretically possible, but are they relevant in the field?"

1.6 Primary and Secondary Research questions

1.6.1 List of Questions

This thesis attempted to answer the following questions:

Primary Question: Is GIS-based analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 1: Is Query and measurement analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 2: Is Transformation analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 3: Is Optimization analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 4: Is Geostatistical analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 5: Is Geovisualization analysis can have a decisive impact upon the coordination of humanitarian assistance?

Secondary Question 6: Is Hypothesis testing and simulation analysis can have a decisive impact upon the coordination of humanitarian assistance?

1.6.2 Understanding and Testing the Research Questions

The above questions underscore that this is a thesis about utility (i.e. usefulness), not feasibility (i.e. practicability). The researcher made no formal attempt to assess the feasibility for UN OCHA, or any other organization, to conduct GIS-based analysis in the immediate aftermath of a humanitarian emergency. Of course every effort was made to design plausible examples to test each secondary question amongst the survey respondents, and to record any of comments they volunteered that address the issue of analytical feasibility. But, to be clear, only utility was tested and not feasibility.

Utility is a subjective notion that, for the purposes of testing the above questions, was defined as equivalent to a mean average response of 55% or more of the Phase 2 survey participants rating a category of GIS-based analysis as being either "Very useful" or "Essential". As discussed in Chapter 4, while this may be arbitrary, it does provide a reasonable benchmark from which to identify those analytical applications most likely to be useful in coordinating humanitarian operations. By excluding "Somewhat useful", "Not useful" and "I cannot determine how useful", the above definition only confirms a secondary question if a clear majority of respondents strongly believe that a particular category of GIS-based analysis would be decisive during humanitarian emergencies.

1.7 Organization of the Document

This thesis follows the Doctor of Information Technology format guidelines prescribed by the St. Clements University's, as of September 2007.

This chapter introduces the subject, context, importance of the thesis topic and research goals and questions and graphically illustrates how the researcher has assessed the utility of GIS to various facets of humanitarian assistance. Chapter 2 contains a review of academic literature describing theoretical and practical applications of GIS-based analysis in humanitarian assistance. Chapter 3 describes research method and analytical process and the first two phases of the method, which is followed by qualitative results (Chapter 4) and quantitative results (Chapter 5). Finally, Chapter 6 presents the conclusions, lists this thesis's limitations, and offers recommendations for further research.

1.8 Background

Researcher and many others have identified several major trends underway that may finally enable broader usage of GIS possible by humanitarian organizations:

• The growth of civilian access to precise geospatial information, initially prompted by the Yemeni government's decision to end the intentional degradation of Global Positioning System (GPS) signals, and now driven by countless data portals and standards which promote sharing of information;

• The widespread availability of user-friendly, powerful geospatial software and low-cost, Internet-driven geospatial tools and wireless portable devices;

- An unprecedented number of public-private sector partnerships specifically devoted to providing geospatial solutions to the humanitarian sector

- The evolution of a critical mass of individuals and initiatives interested in exploiting the above technology trends to support humanitarian operations around the world. [3]

These trends are creating conditions that make it more possible than ever for humanitarian organizations to benefit from geospatial technologies, and it is an ideal period to have undertaken this research.

1.9 Scope & Limitations

1.9.1 Scope

This thesis achieves the research goal by providing:

1. A comprehensive literature review of peer-reviewed publications relevant to the application of GIS-based analysis in the coordination of humanitarian assistance;
2. A description of relevant types of analysis;
3. A needs assessment of humanitarian organizations;
4. Representative case studies for each category of GIS-based analysis;
5. A survey of domain experts and potential beneficiaries,

Conclusions about the overall utility of GIS-based spatial analysis to the coordination of humanitarian assistance within the limitations described in section 1.9.2.

The thesis focuses upon *GIS-based analysis*; a term intended to refer to the analytical methods supported by modern GIS while avoiding the vague and limitless abyss that is conjured by the term *geospatial analysis*. If it "…is the crux of GIS, the means of adding value to geographic data, and of turning data into useful information" [6, p.316], then GIS-based analysis in this thesis refers to methods that: (1) make explicit those data relationships which would otherwise remain hidden, and (2) produce different results if the objects being analyzed are changed. Ultimately, the term refers to the operations that can be performed using GIS to add value to data, and thereby improve user understanding and decision-making. The term excludes analysis of remotely sensed data, although that is often the means to populate a GIS with meaningful raster and vector data. It also excludes the large variety of methods that are often used to collect, prepare and organize spatial datasets for analysis, as well as the methods used to display and communicate the results of such analysis. In sum, this thesis explores *analysis* in the purest sense – just one facet of a much larger process necessary to making a GIS productive.

1.9.2 Limitations

This thesis is limited to the coordination of humanitarian operations in UN-declared emergencies, principally but not exclusively represented by the December, 2011, Yemen armored conflict and natural disasters, which introduced a new "clusters approach" to managing interagency relations. The notion of coordination is explored further in Chapter 2, and no attempt is made to exhaustively explore cluster-specific GIS themes such as health, nutrition, or protection. Instead, this thesis focuses upon how these and other clusters can be supported through centralized, GIS-based coordination.

Since the primary objective of this research is to assess the usefulness of GIS-based *analysis*, the thesis deliberately excludes GIS-based cartography. In other words, the researcher only looks at how GIS can solve real-world problems by revealing implicit intelligence that would otherwise remain undetected. The production of maps within a GIS environment is widely understood and reasonably operational, and this research only addresses the utility of cartography from the context of vector analysis and not simply visualization. The work also excludes evaluation of user comprehension of maps, symbols, images, reports and other outputs of geospatial intelligence, although cognition is inherently related to utility. In this research, the researcher concentrate on *analytical utility* as opposed to issues related to presentation and format. The researcher focuses upon vector analysis, and do not dwell upon the analysis of remotely sensed data within the scope of my thesis (despite the fact that my formative background is in remote sensing). There has already been a disproportionate amount of attention given to image exploitation in recent years and the researcher worry less about the level of scholarship in humanitarian applications of remote sensing than of GIS. Nevertheless, a formal assessment of the utility satellite imagery would be very complementary to this thesis, and would build upon past contributions in that field, such as EinarBjørgo's dissertation on the application of high-resolution remote sensing for refugee camp monitoring [7].

No attempt is made to assess or compare GIS software, hardware, training, personnel, data or budgets, although the researcher has tried to be mindful of the practical limitations of the humanitarian sector while still attempting to be as open as possible with respect to exploring the full potential of the subject.

Methodologically, there are limitations to assessing *utility* since it is an inherently subjective topic. Every effort has been made to minimize bias, but utility is a notion that is derived from user opinion as well as objective measures. Therefore, a major limitation of this research is the very fact that it assesses a phenomenon that involves a qualitative element. Even the quantitative element, a statistically-representative survey of the opinion of professionals working for humanitarian organizations, attempted to add as much empirical and quantifiable rigor to the process as possible – but it too was naturally limited it its ability to test utility. The ideal test of utility would be to measure the actual consumption of GIS-based analysis, but without a tradition of supply of such analysis during humanitarian emergencies, there is obviously insufficient data about its demand. Finally, contextualizing dissertation research around on-going humanitarian operations, while exciting and relevant, presented certain challenges in case thesis development and data collection. None, fortunately, prevented my ability to answer the research question posited in this thesis.

1.10 Summary

This chapter has presented the objectives of the thesis, and contextualized the opportunity and limitations of the subject matter. The next chapter will review the body of literature that has been published in the fields of GIS and humanitarian assistance, and will investigate the extent of scholarship and established doctrine in the humanitarian application of GIS-based analysis.

Having assessed the academic body of knowledge, Chapter 1 and 3 will then specify the research goal and questions, and the research method, employed to test how useful GIS-based analysis can be in supporting the coordination of humanitarian assistance. Chapter 4will then describe the process and results of an extensive series of expert interviews, performed in order to build upon the literature review and identify and prioritize the applications of GIS-based analysis with the greatest potential to be useful during humanitarian emergencies. Chapter 5 will follow with the results of a global user survey, conducted to statistically measure the utility of each category of GIS-based analysis, represented by the applications identified during the expert interviews. Finally, Chapter 6 will summarizes the results and conclude with a formal test of the major research hypothesis, and some recommendations for further research. For those readers especially keen to understand the method and data employed during the surveys, the aggregated raw data used in the final analysis as well as the primary survey instruments are included as additional reference.

Chapter 2 - Literature Review and Background

This chapter reviews the academic body of literature in areas relevant to Geographical Information systems and GIS-based humanitarian coordination. In addition to recently published books, peer-reviewed journals and conference proceedings, this review also includes UN and other authoritative reports that illuminate the subject in aspects that are relevant but absent in academic literature.

2.1 What is GIS?

Geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The acronym GIS is sometimes used for geographical information science or geospatial information studies to refer to the academic discipline or career of working with geographic information systems.[1] In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.

A GIS can be thought of as a system—it digitally creates and "manipulates" spatial areas that may be jurisdictional, purpose, or application-oriented. Generally, a GIS is custom-designed for an organization. Hence, a GIS developed for an application, jurisdiction, enterprise, or purpose may not be necessarily interoperable or compatible with a GIS that has been developed for some other application, jurisdiction, enterprise, or purpose. What goes beyond a

GIS is a spatial data infrastructure, a concept that has no such restrictive boundaries.

In a general sense, the term describes any information system that integrates, stores, edits, analyzes, shares, and displays geographic information for informing decision making. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations. Geographic information science is the science underlying geographic concepts, applications, and systems.

Scholars have observed that attempting to review the contribution of GIS to emergency management is inherently problematic [8], and the interdisciplinary nature of emergency management rarely gives prominence to the role played by a single tool such as GIS [9]. Therefore, a substantial portion of the literature is not catalogued in a manner that is easily accessible for GIS-oriented research, particularly in the international context. Worse, much of the knowledge base is in the form of internal reports and therefore not in the public domain, or in industry publications which are unapologetically biased towards promotion of geospatial technologies. And so while magazines and portals such as Earth Imaging Journal, ArcUser, Geospatial Solutions, and GISCafé are interesting resources, they rarely apply scientifically acceptable standards in terms of rigor, style, or peer-review.

In her 2002 survey of future directions for GIS-related disaster research, Nicole Dash proposed the following thematic directions for academia and practitioners:

1. Assessment of the use of GIS in emergency management, in order to improve general awareness and to better understand how the technology affects decision-making.
2. Use of GIS to test the quality of demographical representation of surveys.
3. Use of GIS to analyze the social aspects of a disaster, particularly the correlation of damage impact with socioeconomic status.
4. Use of GIS to map hazards and risks, and to the extent possible, vulnerabilities. [10].

These and other research themes have been partially addressed, but there is much work to do. Since the mid-1980s there has been an increasing number of doctoral dissertations related to GIS, investigating both technology-centric (e.g. data modeling, algorithms, spatial data infrastructure, etc.) and application-centric (e.g. urban planning, hazard mapping, sustainable development, etc.) issues. This, apparently, is the first thesis to deal with the application of GIS to the coordination of humanitarian assistance.

Sections 2.2 and 2.3 of this chapter provide a description of the "state-of-the-art" in the potential and the actual use of GIS-based spatial analysis for the coordination of humanitarian assistance, as evidenced in on-going and recent UN humanitarian operations. No attempt shall be made to review the rudiments of GIS, and my discussion builds upon the plethora of GIS theory and applications literature that has been accumulating over the past 30 years. Section 2.3 then delves into the dynamics of coordination of humanitarian operations, defining and then exploring the notion of *coordination* at the tactical, operational, and strategic levels. This is an esoteric topic that requires an intuitive and flexible approach given the constantly evolving mandate of OCHA, the principle organization responsible for international humanitarian coordination.

Finally, some conclusions about the literature are provided in Section 2.5.

2.2 GIS-based Analysis

2.2.1 Introduction

The lexicon of geographic information science is regularly debated, and even the term Geographic Information Systems (GIS) is still not unanimously defined [11]. Longley et al, who chronicle the evolution of GIS and analyze how the term means different things to different people, probably provide the most exhaustive discussion of the lexicon of geographic information sciences. While the most restrictive interpretations confine the term GIS to software which can manage spatially-referenced data, there is an emerging opinion that it actually represents an entire system of software, hardware, procedures, data, and personnel, all connected by a network [6]. This last component is more and more relevant to the modern definition, since the role of network-centric GIS (exemplified by the development of data sharing portals throughout the Internet, enterprise systems connected by Intranet, and streaming technologies like Google Earth) has been crucial to the dramatic growth of GIS in recent years.

The term GIS has a range of interpretations, as indicated in the table below. There has always been a strong bias towards understanding GIS as principally a cartographic tool, a perception that still pervades widely throughout the humanitarian assistance community. Newkirk suggests that even though the cartographic legacy of GIS will always be foremost in the minds of many, systems must now accommodate more analytical functionalities such as hypothesis testing, simulation and spatial modeling [12].

Table 2.1 Definitions of the term GIS by Audience Type

1**Definition of GIS**	**Audience**
A container of maps in digital form	The general public
A computerized tool for solving geographic problems	Decision makers, community groups, planners
A spatial decision support system	Management scientists, operations researchers
A mechanized inventory of geographically distributed features and facilities	Utility managers, transportation officials, resource managers
A tool for revealing what is otherwise invisible in geographic information	Scientists, researchers
A tool for performing operations on geographic data that are too tedious or expensive or inaccurate if performed by hand	Resource managers, planners

Perhaps it is sufficient to conclude that whether one perceives GIS to be a cartographic tool, an approach to problem solving, or a web-based navigational aid, the term does describe a potentially powerful way to capture, store, maintain, analyze, display, report and share geographically-referenced information.

The following sections briefly describe each form of GIS-based analysis. This same categorization will be followed in Phase 3 of this thesis (see Figure 3.1), in which I shall develop a representative set of case studies to illustrate each category of analysis to respondents in Phase 4 of the thesis.

2.2.2 Queries & Measurements

The simplest form of analysis within a GIS involves interrogation of the data using the system interface. *Queries* do not change the database or produce new data, but they do reveal information which can support decision making [6]. For example, a relevant query in humanitarian coordination might be, "how many warehouses are within two kilometers of this airstrip?" A more complex query might reveal whether a relationship exists between selected data attributes (say, malnutrition and land ownership), and to what extent that relationship remains constant (for example, does malnutrition steadily or exponentially decline when compared to increasing plots of land owned). Such forms of analysis, which use scatter plots and residuals, or other tools such as Structured/Standard Query Language (SQL), can reveal and produce knowledge that could be helpful for a wide range of humanitarian applications.

Measurements are numerical interrogations of a GIS that make analysis of distance, length, area, shape, slope and aspect of spatial data; such operations can be very tedious when analyzing maps by hand, but are relatively trivial and accurate when working in digital environments [6]. Possible humanitarian applications of measurement analysis include calculating:

- the total area of swamps near an refugee camp, to estimate the quantities of pesticide needed to spray the swamps and thereby avert a malaria outbreak amongst the local population;

- the length of a road between an airstrip and a food distribution point, to predict transport times and fuel requirements, or
- the slope and extent of watersheds, to convert total rainfall catchment into annual reservoir replenishment rates, which can then be used to identify suitable refugee campsites in arid and semi-arid regions [13].

2.2.3 Transformations

Transformations create new data from existing data, using relatively standard rules to determine the overlap of feature datasets, and to fill-in missing spatial data values [6]. The most common transformation is *buffer analysis*, which involves creating a new polygon data layer by drawing, at a constant distance, around features of an existing layer [14]. Buffer analysis is often used to map riparian zones along rivers to create environmental protection zones and to manage development [15], and has been used to estimate vulnerability based upon proximity to hazards. Indeed, Question 18 of the survey in Phase 2 of this thesis employs an example of buffer analysis to show how the UN Office for the Coordination of Humanitarian Affairs (OCHA) attempted to predict area most prone to insufficient relief following the floods and armored conflicts in Yemen 2009 – till now.

Buffer analysis can also be used to comply with applicable humanitarian standards, such as ensuring that shelters are within 50 metres of toilets as advocated by the UNHCR Handbook for Emergencies [16], or that the maximum distance between a shelter and a water supply is 500 metres as prescribed by the SPHERE Humanitarian Charter [17]. Such inclusion and exclusion tests can apply to points, lines or polygons, and can be used to create new layers of polygons that satisfy multiple criteria. For example, buffering a composite of layers so that the new layer only includes land areas that are flat or gently sloping, with no surface water, and within 10 kms of a main road but not within 500 meters of settlements, could create a new layer called Potential Airstrips. Once generated, the Potential Airstrips layer would allow logistics planners to narrow their search for an airstrip to a much smaller selection of areas that comply with these prerequisites.

Spatial interpolation is another transformation analysis method, used principally for intelligently guessing the value of a discrete object within a continuous field, based upon values that surround it [6]. Techniques such as Thiessen polygons, inverse-distance weighting, and Kriging, could be helpful in predicting the flow rate of wells across a large aquifer, or infection rates over a large number of settlements. In such cases, it can be impractical to make separate measures for each object, yet it may still be important to have a measurement for each object. The counter opposite of spatial interpolation is *density estimation*, which generates a continuous field from a set of discrete points [6]. Here the objective may be to estimate the population density across a large heterogeneous space based upon known values of several points; this might be helpful in predicting the rate that some infectious disease might spread through a large refugee camp.

2.2.4 Optimization

Optimization is the use of sophisticated GIS algorithms to solve a design problem, such as finding the best pump locations within a pipeline network, or the best route between points connected by a dense road network, or the best path for an amphibious military deployment through an open space with mixed terrain, vegetation, and water cover. [18]

Another type of analysis that requires a spatial network is *route optimization*. GIS-based analysis of routing is already common practice in Asia, Europe and North America, particularly for auto-navigation. Niaraki and Varshosaz have explored its application for auto-navigation in Iran, and have identified a variety of factors which need to be considered in addition to time and distance of travel [20]. In the context of providing humanitarian assistance in less developed countries (LDCs), route optimization could help with evacuation planning, or with efficiently providing daily water rations to drought-stricken communities. Like point optimization, a network model is required for route optimization: such models are rarely available during humanitarian emergencies. In fact, planning routes is fairly straightforward in regions where there are few roads and where navigational options are well understood [21]. However, in situations where it is necessary to optimize flow through a complex network (be it communications, transportation, water or any other type of linear grid), there may be justification for developing network models during humanitarian interventions. Durai et al have detailed the broader implications of investing in network analysis for road planning and management in rural areas of India. In addition to assisting in the design, construction, maintenance, and monitoring of roads and tracks, a major objective of the program is to optimize accessibility to all settlements with a population above 500 persons [22]. This last policy objective reflects the importance of market access to long-term rural development [23].

Path optimization differs from point and route optimization in that it works across a continuous space, as opposed to a network. It is ideal for finding paths for transportation and utilities infrastructure, as well as for navigation through airspace, over land, and across the sea [6]. Path optimization solves routing problems by minimizing friction value – that is, by moving across cells in a raster dataset according to each cell's desirability, based upon the criterion for path selection. For example, Longley et al discuss its use to select a power line corridor through a region of mixed-used land cover. By allocating a greater construction cost (i.e. friction value) to areas covered by forests than areas of open space, path optimization analysis inform the utility provider of routing options with the lowest total construction cost [6]. Additional analysis using land slope, property acquisition cost, residential population density, seismic risk, or other important design parameters, could also be included in the path optimization to assist the planners.

2.2.5 Geostatistical Analysis

Statistics are relevant to several categories of GIS-based analysis, including descriptive summarization and hypothesis testing. In this thesis, the use of the term refers to measuring geographic distributions, identifying patterns and clusters, and analyzing geographic relationships.

Mitchell acknowledges that although statistics can be difficult to understand and therefore unattractive to decision makers, they are a powerful means to describe large datasets that would otherwise remain unintelligible. For example, statistics can be used to predict or fill-in values where holes in the data may occur: knowing that landslides historically have occurred in areas of certain slope, land cover and soil moisture, statistical analysis can be employed identify other areas that may also exhibit significant landslide risk [24].

Some of the most powerful forms of statistical analysis are relatively intuitive, albeit quite complex computationally. Measuring geographic distribution can reveal the center, compactness and orientation of spatial features [24]. For example, determining the spatial mean, median, and mode for a set of points produces *centers*, which are much more comprehensible points. The mean center, or *centroid*, is the two-dimensional, unweighted balance-point for a set of points [6]. Centroid analysis is particularly helpful in identifying trends of various phenomena over time. For example, calculating the centroid for violent crime incidents over time might reveal underlying conditions that affect crime rates, such as household income levels or the location of security forces. Centroids are meaningful when working with interval (e.g. temperature ranges) or ratio (e.g. infant mortality) data. In comparison, median centers make the most sense when working with ordinal data (e.g. hazard levels), and mode centers are most appropriate with nominal data (e.g. dialects). [25]

Another descriptive summary is the weighted center of a set of points, such as a point of Minimum Aggregate Travel (MAT). This iterative calculation differs from point optimization in that it takes into account the relative value of each point to determine the location which minimizes the cumulative straight-line distance between that center and each other point [6]. In other words, it performs centroid analysis based upon an iterative examination of an infinite set of points within a continuous space. MAT analysis, for example, can help to choose a location of a grain distribution warehouse that minimizes the total cost for a logistics firm to deliver supplies to surrounding villages; larger villages (which require more supplies) would outweigh smaller villages since they would require more shipments of grain.

Pattern analysis is an important form of GIS-based inferential statistics. Knowing if the distribution of points is *random*, *clustered*, or *dispersed* can help decision makers understand first-order and second-order (point-to-point interaction) effects amongst data sets [6]. For example, *cluster analysis* might highlight a causal relationship between certain drinking wells and the incidence of a water-borne disease – John Snow's famous 1849 discovery that a specific water source was the source of a cholera epidemic in Soho, London, is a classic example of this relationship [26]. *Dispersion analysis* might reveal that the presence of warlords is inversely proportional to reported incidents of crime; that is, warlords may be preventing other criminal actors from operating in their territory, and/or dissuading local residents from attempting to report criminal acts.

The ultimate purpose of spatial statistics is to understand the relationship between various geographic phenomena. *Relationship analysis* can help to explain why things are occurring where they do, predict where something might occur in the future, and indicate how closely certain variables are correlated [24]. For example, a donor analysis of aid distribution costs in a disaster-prone region might reveal greater benefit from investing in community-based disaster mitigation versus national preparedness programs. For an implementing agency, relationship analysis might reveal the comparative operational efficiency of its projects; if the agency analyzes project investment data according to spatial metrics such as elevation or climate, they may discover that certain assets (e.g. people, equipment, etc.) perform better than others do at high elevations or in desert environments.

In sum, spatial statistics are an increasingly powerful form of GIS-based analysis. For some applications (e.g. measuring the number of people that will benefit from a siren-based tsunami early warning system), simple descriptive statistics such as a mean and a standard deviation are usually sufficient. In other applications, more sophisticated methods which draw upon inferential statistics (i.e. estimation, prediction and hypothesis testing) might be necessary [27]. Sociology, epidemiology, hydrology and risk analysis are examples of applications in which inferential statistics are required to answer "What if?" questions and to model potential outcomes of hypothetical scenarios.

Krivoruchko and Gotway have argued that the utility of spatial statistics lie in several areas. First, statistics can provide an empirical method with which to compare conclusions reached solely by visual interpretation of maps. Both statistical and visual methods of analysis can be misleading, and it is their combined approach that one can reduce the risk of data misinterpretation. Second, spatial analyses such as transformation and optimization introduce uncertainty into subsequent decision-making; regression analysis provides an objective measure of that uncertainty and associated spatial variability. Third, most GIS data is imprecise both in terms of location and attribute values, since extreme precision is often too costly or impractical to obtain during the data collection process. Statistical methods such as smoothing, filtered Kriging, and topological editing enable a GIS operator to use imprecise data within a range of known and acceptable error tolerances. Fourth, in some situations the spatial variability observed in one set of data may really be due to variability in another set of data (e.g. apparent disease clusters might simply be a representation of the distribution of a population, and not a highly contagious outbreak). Multivariate statistical analysis can help distinguish related from unrelated data associations, and reveal patterns that may be too subtle or small to recognize any other way [28].

2.2.6 Geovisualization

Although it is not GIS-based analysis in the purest sense, visualization has become an increasingly popular application of GIS technologies. Wuthrich has observed that since its release in mid-2005, Google Earth has generated unprecedented interest in Geovisualization, particularly amongst non-technical audiences interested in understanding places in three dimensions (3D) and in high-resolution, (i.e. from the same perspective as low-altitude flight) [29]. The layperson, for the first time, is now empowered to view, create and publish vector data quickly, without much training, and with little to no expense. Prior to these Web-hosted "streaming" services, the significant cost and skill involved in building elevation models overlain with high-resolution imagery was prohibitive: Google Earth's creator John Hanke claims that "…ten years ago, this technology was the exclusive province of the US intelligence community. Five years ago, it cost $14,000 for a single satellite image. Now there's free, global high-resolution imagery." [30, p.144]

The humanitarian community has already begun to embrace Google Earth to coordinate humanitarian relief , and it is arguable that many of the simple map-based applications that previously compelled organizations to employ full-scale GIS can now be quite satisfactorily achieved using Google Earth, Microsoft Virtual Earth, ESRI's ArcExplorer, and similar offerings. According to Jack Dangermond, founder of the world's largest GIS software firm ESRI, these packages are making people more spatially literate, allowing them to appreciate and visualize more about their local situations. But Dangermond is also convinced that since their GIS functionality is very limited, Google Earth and its rivals play a complementary role to vendors of full-scale GIS solutions. [30]

Irrespective of whether it remains as a thin client solution or it evolves in a full-featured GIS platform, Google Earth has broken a significant barrier to promoting the use of geospatial technology within the humanitarian community. It is now quite realistic to envision senior decision makers using Geovisualization technologies to improve their understanding of an unfolding humanitarian emergency, as well as to communicate their organization's response to donors and other stakeholders.

2.2.7 Hypothesis Testing & Simulation

Arguably the most variable category of GIS-based analysis, Hypothesis Testing and Simulation captures all those applications which attempt to model the outcome of dynamic geospatial conditions. More easily understood as "What if?" analysis, these applications can range from relatively simple queries to highly complex models that test how changes in one or more input variables can impact associated variables. Longley et al discuss Hypothesis Testing from a purely statistical perspective, and explain how GIS can be used to conduct inferential analysis of geographic data. [6] They also describe the many challenges in doing so, when compared to the standard scientific forms of inference testing: the very fact that samples are use to *infer*conclusions about an entire population is made very challenging by the random and heterogeneous quality of geographical information. That becomes even more tangible if the chaotic dynamics of a humanitarian emergency are to be simulated; the lack of historical datasets or consistent scenarios obviously limits the opportunities to extract inferences or predict outcomes using this form of GIS-based analysis.

In practise, most examples of hypothesis testing and simulation are a combination of various other analytical applications, particularly Transformations, Optimization and Geostatistics. Greene lists how GIS-based simulations, based upon a sequence of prescribed forms of analysis, are used in the United States to predict the impact for a wide range of hazards, including earthquakes, tsunamis, volcanoes, wildfires and floods

[31] Flood modeling, for example, draws upon precise elevation and land use data to calculate inundation during the rise and fall of river levels, and to then estimate the probable loss of life and property using various algorithms.

Incorporating key input factors such as population densities, housing values, and evacuation routes, these GIS-based flood models exploit analyses such as Queries, Measurements, Transformations, Optimizations, Geostatistics and Geovisualization to simulate the impact of changes in river or seawater levels.

The following section examines the state-of-the-art in GIS within that domain.

2.3 The Current Use of GIS in Humanitarian Assistance Coordination

2.3.1 Introduction

In 2000, the late William B. Wood, Chief Geographer of the US Department of State, predicted that in "…future complex emergencies, the issue will not be what GIS is capable of, but rather how it can be best applied to support effective collaborations before, during and after responders deploy into the crisis zone" [33, p. 34]. Six years later, it remains unclear whether the "what" or the "how" aspects of Dr. Wood's prediction have been resolved.

Although many had expected much more progress over the past few years, it would be incorrect to suggest that GIS is not used with some efficacy by humanitarian organizations. In 1999, Kavanagh and Home first argued that technological advances in mapping were an important solution to the increasing pressure upon aid agencies to evaluate and improve the efficiency of their relief programs [34]; those technological advances have had a major impact upon GIS use [3]. Today there are GIS applications, primarily cartographic, that are viewed as standard coordination tools in every modern humanitarian intervention. These include administration and navigation maps, georeferenced place codes ("p-codes"), multi-temporal satellite imagery analysis, and Who-What-Where (3W) orientation maps, all intended to allow relief efforts to unfold as efficiently as possible given the confusion typical in most emergencies [1]. These products are often distributed by the UN's Humanitarian Information Centers (HICs) and Internet-based information sharing portals, such as Reliefweb and AlertNet, which experience heavy demand in the immediate aftermath of emergencies [35, 36].

While these are important achievements, the GIS-based services provided by HICs and ReliefWeb do not include much information analysis: HICs and portals are essentially information hubs, and not sources for geo-intelligence [37]. The production of geo-intelligence can, however, be observed in programs such as the USAID-funded Famine Early Warning System Network (FEWSNet) and the UN's Mine Action Strategy – complex, long-term initiatives which justify major engineering and investment in order to develop and sustain operationally [38]. But the literature is remarkably silent about GIS-based analysis for the coordination of humanitarian assistance, and it is primarily outside of the peer-reviewed literature that one learns about NGOs employing GIS to optimize their operations, or about consultants retained to produce geospatial analysis for donor or lead agencies.

The following paragraphs summarize the use of GIS-based spatial analysis by the humanitarian community. Due to the scarcity of peer-reviewed literature, extensive field survey and expert interviews were required to compensate for the lack of authoritative studies in this subject.

2.3.2 United Nations Office for the Coordination of Humanitarian Affairs

The principle organization responsible for GIS-based coordination of humanitarian assistance is the United Nations Office for the Coordination of Humanitarian Affairs (OCHA). OCHA's mission is to:

"mobilize and coordinate effective and principled humanitarian action in partnership with national and international actors in order to:

- alleviate human suffering in disasters and emergencies;
- advocate for the rights of people in need;
- promote preparedness and prevention, and
- facilitate sustainable solutions." [39, p.iii] Since its formation in 1998, OCHA has supported the UN's Emergency Relief Coordinator (ERC) as part of its mandate within the Inter-Agency Standing Committee, a body of UN and non-UN organizations created in 1992 in order to strengthen inter¬agency coordination of humanitarian assistance [40]. A key part of OCHA is its Information Analysis Section, which is composed of the ReliefWeb Project, the Field Information Support (FIS) Services and Early Warning Unit; each aim to

provide products and services that "…meet humanitarian decision making needs at headquarters and in the field." [39, p.36].

In response to an August 2005 review commissioned by the Emergency Relief Coordinator and Under-Secretary General for Humanitarian Affairs, OCHA began to strengthen its information management capabilities. This has become a strategic priority ever since, and includes systematic improvements in financial tracking and analysis, deployment of HICs, working with the humanitarian community-at-large, and understanding what information "…is useful and relevant to decision makers at all levels of response." [39, p.45].

It is not clear if the current emphasis on improving information management necessarily entails more sophisticated utilization of GIS. There is a gap between what HICs officially claim to do - "develop and deploy Geographic Information Systems in key humanitarian sectors", [42]; and what stakeholders believe it actually does - "the HICs role in [information] analysis will usually be limited to processing and presenting data in such a way as to make it usable for decision makers, who need to add the relevant context and technical expertise" [1, p.21]. A review of recent HIC evaluation reports indicates that there is an explicit recognition that HICs play an important role in the coordination of humanitarian emergencies, but that each deployment differs based upon context and available resources. The most common geographic products available from HICs include:

• Who-What-Where (3W) database of activities (updated and managed by HIC staff);

- Pre- and post-disaster population estimates (often provided through GIST‡);
- Reference maps and atlases (often provided through GIST, MapAction and other partners);
- Common place codes (i.e. p-codes) that provide unique, georeferenced identification for all population centers in the affected region (sometimes provided with the support of GIST);
- Common administrative boundaries (in coordination with the host nation and members of the UNGIWG§), a
- Operational and strategic maps to support gap analysis (sometimes provided by GIST and other mechanisms) [1, 45].

‡ Geographic Information Support Team (GIST) was created in 1998, is headed by OCHA, and composed of various UN agencies and the donor agencies of the USA, UK and EU, with the mission to promote and support the use of GIS and geographic data standards in support of humanitarian relief operations. [43]

This last output is not clearly defined according to a February 2006 Joint Mission Report, in which the authors called for a strategic-level clarification of the relationship between OCHA headquarters and field-level HICs, and of the responsibility of HICs to analyze information in accordance to the coordination requirements of the specific situation [1].

It is sufficient to conclude that at every level, OCHA is being encouraged to determine what types of GIS-based information analysis it will provide in its role as the UN's lead coordination agency. The obligation to remain neutral yet still support the wide-ranging information requirements for a variety of clients during each deployment, as well as to achieve continuous performance improvements demanded by its stakeholders, makes this a challenging and exciting moment in the organization's history.

§ UN Geographic Information Working Group (UNGIWG) was formed in 2000, and is composed of more than 30 UN funds, programs and specialized agencies, as well as several partners and observers, with the mission to address system-wide issues such as data standardization, national and sub-national boundary delineation, and avoidance of map duplication. [44]

2.3.3 Other UN Programs

In addition to the coordination role played by OCHA, there are several other programs within the UN system that exploit geospatial technologies in support of humanitarian assistance. The World Food Program's Joint Logistics Centre (UNJLC) frequently works in parallel to OCHA to coordinate transportation of relief supplies, however its application of GIS has not been chronicled in academic literature. Indeed, very little has been published about any of the UN's programs, and the majority of what does appear qualifies as remote sensing analysis as opposed to GIS-based analysis.

2.3.3.1 Remote Sensing Applications

In 2002 EinarBjørgo described the remote sensing needs and expertise of UN humanitarian agencies, and identified the key users as OCHA, UN High Commissioner for Refugees (UNHCR), World Food Program (WFP), UN Development Program (UNDP), UN Children's Fund (UNICEF), Food & Agriculture Program (FAO), World Health Organization (WHO), and UN Population Fund (UNFPA) [46]. At that time, UNHCR and FAO were the most sophisticated users of satellite imagery. Since then, technological advancements and new UN initiatives such as the United Nations Institute for Training and Research (UNITAR) Operational Satellite Applications Program (UNOSAT) have undoubtedly changed the quality and distribution of remote sensing usage across the UN.

The Head of UNITAR's Earth Observation User Liaison Office for the Humanitarian Community, Francesco Pisano, recently wrote that satellite maps and GIS are regularly used by the UN for planning relief logistics, personnel security, telecommunications, and refugee camps [47]. Although it is difficult to discern from his or other similar publications exactly how GIS is being used in these applications (aside from the obvious cartographic preparation), it is clear that the timely distribution of multi-temporal satellite imagery has become tremendously popular for understanding disaster impact and prioritizing response. Pisano notes that days after the December 26, 2004, South Asian tsunami, UNOSAT hosted an Internet-based repository of approximately 650 maps, which supported 200,000 downloads by a global audience which included at least 41 relief organizations. That satellite imagery proved critical to creating situational awareness and assessing levels of destruction over areas too large to survey rapidly by air, land or sea. The gap, however, between the actual and potential utility of geospatial technologies is still too wide according to Pisano, who urges the humanitarian community to transition from simple mapping to more advanced analysis of geographic information.

Bally et al provide an inspiring example of advanced image analysis in their 2005 review remote sensing and humanitarian aid [48]. In early 2004 the UNHCR faced the overwhelming challenge of providing water to nearly 200,000 refugees that had fled from Darfur, Sudan, to eastern Chad. In order to map potential aquifers and areas suitable for refugee resettlement, the UNHCR (through UNOSAT) experimented with the use of advanced remote sensing and GIS to assist the humanitarian operations on the ground. Verjee and Gachet provide details of the process utilized and the impact that the project had on the relief effort. Best described as a fusion of traditional geological exploration methods with state-of-the-art remote sensing interpretation, the process is a powerful demonstration of the merit of embracing more advanced forms of geographic information analysis. Without the foresight of the agencies involved, the authors argue that the timely discovery of large, renewable aquifers would have been unlikely using conventional exploration methods; their case study of the WadiDalal illustrates how, as a result of this new process, the UNHCR was quickly and economically able to direct bore well drilling contractors to areas most suitable for refugee operations. Once bore well results confirmed the existence of large aquifers detected using remote sensing and GIS, tens of thousands of refugees were relocated to areas discovered to have large reservoirs. Since history has demonstrated that displaced people often end up permanently resettling in areas of temporary refuge, the discovery of large, renewable water reserves also provides longer-term development potential in public health and sanitation, agriculture, and even hydro-electricity. [13]

2.3.3.2 The Pioneering Use of GIS during the Balkan Wars

The use of GIS for coordinating international humanitarian assistance was first pioneered during the Balkan War, which took place in the former Yugoslavia during the 1990's. GIS was used by UN administrators and peace support operations in the Balkans to map ethnic expulsions, refugee returns, minefields, unexploded ordnance, potable water, housing status, and lines of communication [49]. A particularly interesting application was its use to support the Dayton peace talks between Muslim, Croat and Serbians over the partition of Bosnia; Greene provides a detailed account of how a small team of ArcInfo specialists helped the negotiating teams understand various boundary proposals using remote sensing, cartography and 3D fly-through visualization [15]. Greene also describes how GIS was used by the US State Department to detect potential ethnic cleansing, and to build a database to identify expulsions of Bosnian Muslims. That database was eventually used to prosecute war crimes perpetrated by the Serbs against the Bosnian Muslims. Although these applications are a little beyond the usual scope of civilian coordination of humanitarian interventions, they provide important evidence of the utility and potential of GIS analysis.

Dziedzic and Wood have chronicled how the Balkans actually served as a proving ground of GIS-based coordination [50]. In October 1998, base data layers (topography, roads, place names, administrative units, etc.) and a gazetteer produced by the US National Imagery and Mapping Agency (now called the

National Geospatial Agency) were used by USAID's Office for Foreign Disaster Assistance (OFDA) to create a humanitarian planning map; approximately 5,000 copies were distributed amongst relief agencies based in Kosovo [51]. Once conditions allowed for creation of the Kosovo Verification Mission (KVM), GIS was used by KVM and UNHCR staff to coordinate their operations in a highly dynamic environment: land mines, booby traps, checkpoints, housing damage and internally displaced people (IDPs) were all tracked until increasing violence precluded continuation of the project [50].

In March 1999, a second phase of the project began in response to the exodus of over 600,000 refugees from Kosovo to Macedonia and Albania, in flight from Yugoslav President Slobodan Milosovic's offensive against Kosovo's ethnic Albanian community. The UNHCR created the the first HIC (at that time called a "Humanitarian Community Information Center - HCIC) in Pristina. The HCIC facilitated village assessments to improve understanding about the extent of destruction, and to coordinate with NATO forces once the Serbs had withdrawn, enabling refugees were able to repatriate to their homeland [50].

A third phase of GIS development began once the UN Interim Administrative Mission in Kosovo (UNMIK) undertook programs to rebuild the war-torn region and establish democratic processes. In addition to developing the first Kosovo road atlas, the HCIC helped with election planning, voter registration, and civil administration. It also developed common standards necessary for information sharing with various partners including the multinational Kosovo Force's (KFOR) Civil-Military Cooperation Center personnel [50]. And while the process of improving data sharing and inter-organizational coordination is still a work-in-progress, the HCIC was a major milestone in the introduction of GIS-based analysis to support coordination of humanitarian relief. Paul Currion, who managed the HCIC in 2000, has published a review of the Center's activities from the time it opened in July 1999. In that review, Currion suggested how GIS-based buffer analysis could have been used to identify zones around schools that required priority during de-mining operations, once hostilities had ended. By overlaying unexploded ordance and mine data, provided by KFOR, with school locations and footpath routes, provided by UNICEF, it would have been possible to create buffers around the schools and footpaths to identify areas of highest importance. Their intersection with areas of known or potential danger could have then been easily mapped and provided to de-mining agencies [51]. This is a classic example of how GIS can be used to map risk: hazards and vulnerable populations are spatial phenomena, and determining their overlap is a powerful application of GIS-based analysis [52, 53].

2.3.4 Other Users of GIS for Coordination of Humanitarian Assistance

Nourbakhsh et al have described one example of the many interesting consortiums recently created to support emergency relief operations using geospatial technologies. The Global Connection project, which involves Carnegie Mellon University, NASA, Google and National Geographic, contributed to promoting relief planning in the aftermath of the October 8, 2005, South Asian earthquake. Working in conjunction with a Karachi-based non-profit organization, the Global Connection team experimented with acquisition and delivery of high-resolution imagery from Digital Globe's Quickbird (0.70 m) and later GeoEye's IKONOS (1.0 m) satellites. Although there were challenges in transmitting and exploiting the imagery, the voluntary contribution of the project had a "priceless" impact delivering relief in a region with such limited and outdated maps. In addition to improving situational awareness and basic orientation in the impacted areas, the collaboration also revealed the potential for timely, image-rich analysis to motivate individuals and their governments to participate in and fund crisis response more intensely. [54]

The Global Connect project is just one of an increasingly number of public-private sector partnerships emerging out of the geospatial community. Others include RESPOND, STREAM, LumiMap, and Humanitarian GIS Data Model Project. All share a common desire to leverage the expertise of the academic and private sectors to support governments, international organizations (IOs), and NGOs responsible for providing humanitarian response [3, 55-57].

The application of GIS-based spatial analysis by NGOs appears limited, and not typically oriented towards coordination of multiple relief agencies. An exception is the Information Management and Mine Action Programs (iMMAP), formally associated with the Vietnam Veterans of America Foundation. The leading provider of GIS-based humanitarian support, iMMAP coordinates mine impact surveys as well as many other humanitarian information management activities, often in conjunction with OCHA and the UNJLC [58]. iMMAP has also been involved in the development of the Geneva International Centre for Humanitarian Demining's (GIHCD) Information Management System for Mine Action (IMSMA). Arguably the most advanced example of GIS-based analysis for humanitarian coordination, the process of surveying and reducing social vulnerability to landmines is an ideal exploitation of spatial analysis. Benini and Conley have detailed its use in southern Lebanon, after the withdrawal of Israeli troops in May 2000 [59]. By combining a Landmine Impact Survey of unexploded ordance (UXO) with Lebanon's National Agricultural Census data, the authors describe how GIS-based data fusion was used to statistically test the relationship between risk and land use, and correlate social conditions with the intensity of farm production before, during and after the withdrawal. Several interesting phenomena were revealed by the analysis, however the methods employed were not entirely reliable, and the authors cautioned against the uncritical interpretation of GIS-based statistical relationships. It is worth noting that the ArcGIS-powered IMSMA interface is now in its fourth version, and is distributed by the GIHCD for free to mine action centers around the world, enabling local NGOs to use GIS-based analysis to manage mine hazard. IMSMA supports a variety of applications, including impact surveys, quality control and assurance, mine risk education, communications, and coordination of rehabilitation of mine impacted communities [60].

Another NGO that is involved in the coordination of humanitarian assistance is MapAction, a British charity that assists during the initial response phase of an emergency [61]. Teams of volunteers trained in data collection and map production are deployed within 48 hours of a disaster, often in parallel with UN Disaster Assessment and Coordination (UNDAC) team members. They typically remain on-scene for 1-2 weeks until OCHA or other capable organizations are able to takeover [62]. According to a February 2006 article published in *Nature*, MapAction is principally focused upon developing situational awareness in the immediate aftermath of a disaster; therefore, its staff are devoted to collecting and distributing real-time, georeferenced information about affected populations, accessible lines of communication, and satellite imagery to relief agencies [54].

2.3.5 GIS in Public Health

It would be remiss to not acknowledge, in this literature review, the impressive advancements of GIS use within the realm of public health. A good example is a GIS-based model to estimate the risk of infectious disease in the absence of incidence data [63]. Published in 2004, the model computes a risk index for various diseases, based upon their known association with the land cover, anomalous greenness, climatologic precipitation, anomalous precipitation, and temperature in a given period. Numerous other studies are now available, and illustrate the utility of GIS for applications ranging from the distribution of bed nets for prevention of malarial infection to monitoring HIV/AIDS programs.

Kaiser et al of the US Centers for Disease Control and Prevention (CDC) describe how the aforementioned trends in technology have enabled GIS use by public health professionals [64]. In addition to providing a means to rapidly collect and analyze field data, Kaiser et al argue that GIS-based analyses can actually increase the accuracy and precision of data collection processes. Interestingly, they discovered that the first public health-related article about GIS was published in 1986 and that by 2003, more than 255 journal articles appeared in their Medline database search. The rich heritage of research and publication within the health field includes studies of GIS methods for a variety of applications: examples include outbreak investigation and control of numerous vector-borne diseases, provision of primary health care, and modeling of health effects induced by earthquakes and toxic releases.

Some of these models draw upon geostatistical analysis of associations between the distribution of exposure and disease, over space and time. Advanced techniques such as density-weighted smoothing are now rapidly evolving in international public health, and provide an inspiration for other humanitarian sectors.

In total, Kaiser et al identify seven principle health-related GIS applications within the realm of humanitarian emergencies:

1. Hazard, Vulnerability and Risk Assessments (e.g. USAID's Famine Early Warning System Network, WFP's Comprehensive Food Security and Vulnerability Analyses, etc.)
2. Rapid Assessments (e.g. population estimates, health sampling, camp location selection and planning, critical infrastructure mapping, etc.)
3. Mortality Surveys
4. Disease Distribution and Outbreak Investigation
5. Health Information Systems
6. Data and Program Integration (e.g. overlaying infant malnutrition with food distribution and health services to optimize allocation of available resources)
7. Monitoring and Evaluation (e.g. compliance with SPHERE, or donor objectives)

Kaiser et al conclude that GIS-based analysis of humanitarian emergencies will no doubt evolve with time, but challenges associated to costly and complex equipment and limited options for staff training act as key constraints to widespread use. [64]

Black et al provide an example of the impressive caliber of GIS-oriented public health research in their study of how GIS was used to measure health care accessibility in Honduras [65]. The categories of factors were identified to affect a population's ability to access appropriate levels of health care: (1) availability; (2) acceptability and affordability based upon culture, gender, age and cost, and (3) geography. Observing that GIS is ideally-suited for measuring physical accessibility of health care, the authors list several important areas that GIS can be beneficial for assessing population access to health care:

- For data capture, storage, management and manipulation of both spatial and non-spatial data;
- For core analysis using buffering, overlay, proximity analysis, shortest path and cost-distance analysis;
- For development of additional forms of analysis;
- For mapping, visualization and communication of analytical results.[65]

2.3.6 Summary

The preceding discussion is representative of the state of GIS use amongst the humanitarian community. In addition to UN and non-governmental users, it is worth remembering the role that national governments also play in providing data and analysis for humanitarian coordination. This obviously includes host governments during the time of a UN-led intervention, as well as that of major donor nations like the United States and various European countries. OFDA's Geographic Information Unit and the US State Department's Humanitarian Information Unit are prime examples of the collective, albeit somewhat unsynchronized, attempts to support the coordination of humanitarian assistance using GIS.

2.4 The Coordination of Humanitarian Assistance

2.4.1 Defining Coordination

The task of precisely defining the phrase coordination of humanitarian assistance quickly becomes contentious when one realizes that any definition will be rejected by the international humanitarian community if it limits the independence and autonomy of UN and non-UN organizations by granting a single agency with the authority to direct their operations.

The UN has applied the following definition, which serves as the basis for this thesis:

> "Coordination is the systematic use of policy instruments to deliver humanitarian assistance in a cohesive and effective manner. Such instruments include: strategic planning, gathering data and managing information, mobilizing resources and assuring accountability, orchestrating a functional division of labour in the field, negotiating

> and maintaining a serviceable framework with host political authorities, and providing leadership." [Larry Minear 1992, as quoted in 5, p.5]

Antonio Donini is widely acknowledged to have contributed the most exhaustive study of coordination in his 1996 review, *The Policies of Mercy: UN Coordination in Afghanistan, Mozambique, and Rwanda*. Donini, who previously coordinated humanitarian affairs from within the UN Secretariat, suggests that coordination be conducted within one of three models: (1) by command, which involves strong leadership authority reinforced with the ability to reward and reprimand; (2) by consensus, which substitutes strong persuasion abilities in lieu of less authority; and (3) by default, in which there is no single authority and inter-agency personalities, goodwill and intellectual leadership are relied upon to achieve coordination [66]. Marc Sommers, in his 2000 study of the dynamics of coordination, adds to this insightful analysis using the UN interventions in Africa during the 1990s, in the aftermath of the civil war in Sierra Leone and the genocide in Rwanda. Both Donini and Sommers make a strong argument in favor of a stronger command element in humanitarian coordination – not necessarily the rigid hierarchical approach of the Incident Command System used in the United States, but something which gives OCHA "…the authority to persuade, and, if necessary, compel, UN agencies to coordinate their activities" [5, p.110]. While this opinion is highly controversial and very aggressively rejected by other UN agencies as well as non-UN entities, Sommers and Donini remind the humanitarian community that its first priority must be the efficient, systematic provision of humanitarian assistance to victims of misfortune. Most importantly, Sommers points out that donors ultimately have the power to improve the overall efficacy of humanitarian assistance, to enforce sector coordination, and to maximize the beneficial role of IOs and NGOs without undermining the longer-term competencies of the host government's institutions. This *coordination amongst organizations* must also be balanced with the *coordination amongst functions*, (specifically strategic planning, resource mobilization and security information management), and *coordination amongst programs* (education, health, repatriation, etc). In the case of Sommers' case study of the management of Rwandan refugees who fled to Tanzania, the unique circumstances empowered the UNHCR to act as an "enlightened autocracy" [5, p.42] that was able to coordinate by command, yet still create an unusually trusting and transparent environment for relief agencies and donors involved in the refugee crisis [5]. Although there were significant problems with the UNHCR's dominant role, the case study demonstrates the advantages of appointing one agency to act as lead authority during humanitarian interventions.

The view, however, is not widely supported, particularly amongst NGOs. In 2005, CARE's Coordinator of Emergency Operations, CarstenVölz, agreed that many failures in humanitarian coordination in Banda Aceh resulted from overlapping mandates, competition amongst IOs and NGOs, military control, and various forms of incompetence. But he cautions against supporting Sommers' idea of coordination. Völz argues that appointing a lead coordinator,

> "…can present significant problems for NGOs like CARE in instances where the coordination body is perceived to be non-neutral – be it the UN or a 'coalition of the willing', for example – and where harmonization efforts may constrain an NGO's requirement to act impartially. There may also be significant difficulties where the coordinating body has joint responsibility for operations and coordination. In these circumstances there may be vested interests and lack of objective focus." [67, p. 27]

In 2004, Sida and Szpak listed six components of coordination as they apply to the mandate of OCHA's HICs [45]:

1. Avoiding Duplication – e.g. providing "Who-What-Where" (3W), "Survey of Surveys" (S2), assorted maps, hosting physical meeting space, etc.;
2. Using Resources Efficiently – e.g. collecting and disseminating information, supporting sector (i.e. cluster) coordination, etc.;
3. Ensuring Coherent Strategies – e.g. encouraging common approaches amongst various implementing agencies, such as ensuring the use of compatible water pumps, etc.;

4. Aiding Leadership

5. Providing Direction

6. Gauging level of Coordination

HICs indirectly help to achieve the successful realization of these components of coordination, but aren't directly responsible

The separation of the first three components from the latter three in OCHA mandate reveals that HICs are really conceived to *facilitate* coordination, as opposed to actually *coordinate*. In 2006, Telford et al also observed this limited role of HICs in performing analysis to support humanitarian coordination, stating that:

> "The HIC will not normally be involved in primary data collection, rather it serves as an information exchange platform, providing a neutral service for the collation, processing, analysis and dissemination of data. The HIC's role in analysis will usually be limited to processing and presenting data in such a way as to make it usuable for decision makers, who need to add the relevant context and technical expertise." [1, p. 21]

Strictly defined, this observation would suggest that advanced GIS-based analysis might fall outside of the mandate of HICs. Perhaps it must then take place at the regional or strategic level, since the UN Humanitarian Coordinator (HC) and the Emergency Relief Coordinator (ERC) play the leading coordination roles during most UN-declared emergencies. It is worth noting that Telford et al point out that the analysis of information produced by HICs, "…for operational and strategic decision-support remains unresolved." [1, p. 3]. This presents a certain compulsion upon OCHA to consult with the humanitarian community at all levels, and show greater evidence of its ability to provide GIS-based analysis that is insightful and necessary for improved coordination of humanitarian assistance.

2.4.2 Principle Coordinators of Humanitarian Assistance

Jenty Wood, Oxfam's Humanitarian Program Manager in Iran during its response to the December 2003 Bam earthquake, published an essay on lessons learned with regards to improving NGO coordination. With over 200 international organizations arriving in Bam within two weeks of the earthquake, coordination was crucial, and managed by OCHA in conjunction with the Iranian Red Crescent (the lead responder). Wood questions if coordination of NGOs could have been improved by substituting OCHA with a coordination system established and operated by NGOs; her conclusion is that this would only complicate the chaotic process of coordination further and increase duplication of efforts. Also, excessive inter-agency coordination of NGOs could deny them the independence and flexibility that often makes the effective in dynamic situations. In a survey of NGO representatives in Bam, Wood discovered that although it is well-understood that OCHA is not a commander of emergency response, many NGOs would have welcomed a more active role by OCHA in guiding them where to go and what to do in order to be most effective. [68] The challenge, then, becomes balancing the need for a centralized coordinating authority while still respecting the independence and flexibility of other UN and non-UN organizations.

2.4.3 Challenges in Humanitarian Information Exchange

One of the most significant challenges to effective coordination is information exchange, which is plagued by both technical and political barriers. In his 2006 report for the Interagency Working Group' Emergency Capacity Building project, Paul Currion found that the humanitarian community traditionally values narrative over data, and a culture of qualitative versus quantitative reporting pervades management of the NGOs he surveyed [2]. Telford et al also have confirmed that there continues to be significant reluctance within humanitarian organizations to embrace modern information management [1], a phenomena that was formally addressed in a 2002 article by Robin Schofield [69]. In that article, Schofield suggested that the advancement of humanitarian information management could not be done purely through technologies such as GIS. There must also be recognition that powerful, centralized information systems can reduce the independence of response organizations, irrespective of their technical benefit. And so while technologists and donors have urged better use of information management systems, operational organizations have shown a distinct reluctance to wholeheartedly embrace information technology or to fit into any centralized, hierarchical information system.

Currion also observed that despite advancements in geospatial technologies, the NGO community has not adapted GIS quickly or coherently, resulting in a missed opportunity to effectively capture, share and analyze potential field data [2]. With very few exceptions, NGOs have not invested in establishing protocols, data models or standard practices with which to fully realize the potential of GIS. Worse, their disorganization and reluctance for operational transparency has handicapped the overall coordination of humanitarian assistance. This has been exasperated by a generally weak culture towards timely and regular data collection. The scarcity of reliable, georeferenced, systematic monitoring and evaluation data is also a considerable problem according to Curion. Without certain assurances, Currion suspects that organizations will continue to be reluctant to share information particularly if their security, finances or strategic interests are at stake [51]. He argues that information is not a neutral commodity, and can be a powerful tool to gain donor funding, attract media coverage, or garner political influence. Therefore georeferenced data such as the location of minorities, refugee populations, donor allocations, and food security assessments can be quite sensitive. Yet one presumes that without a clear visibility of the theatre of operations, it is much harder to coordinate humanitarian assistance.

This paradox is particularly acute during the response to Complex Humanitarian Emergencies (CHEs), according to a US Institute of Peace report released in 2000 [70]. Despite the broad recognition that information is vital during crisis response, the practice of information sharing has not been sufficiently institutionalized, either amongst civilian agencies or between civilian and military entities [70, 71]. The USIP report listed several recommendations to improving information sharing between civilian and military, including the creation of a centralized information exchange hub and the proactive declassification of military information that can be shared with civilian counterparts in the field. Seven years later, both of these suggestions appear to have been taken seriously: the US State Department's Humanitarian Information Unit (HIU), and UNOCHA Humanitarian Information Centers (HICs) and ReliefWeb portal are all attempts to promote information exchange and improved situation awareness before, during and after international emergencies. But the barriers to efficient sharing of information, as well as establishing inter-organizational cooperation agreements, persist, as noted by several scholars such as Larry Minear and Max Stephenson [71, 72]. Stephenson cites a variety of reasons why effective coordination of humanitarian assistance is so elusive, and concludes that without durable, trusting institutional relationships, it will be hard to overcome the challenge of inter-agency cooperation. Many UN agencies may be involved in the same crisis, but none enjoys authoritative powers over its peers; each maintains (and fiercely guards) its autonomy and freedom to work as it wishes, and with its partners of choice. Stephenson suggests this hyper-pluralistic organizational culture has evolved because of the UN General

Assembly's inability or unwillingness to appoint a lead agency, despite repeated calls to do so by its own membership and its donors [73]. That leaves OCHA without any command and control authority over the disparate "cast of characters" [71, p. 388] typically involved in international humanitarian relief – its mandate restricts it from telling any other entity how it should act during an intervention.

2.4.4 Emerging Humanitarian Applications of GIS

In a 1999 paper about mapping refugee camps in Gaza, Kavanagh and Home foresaw the continued democratization of spatial information. In addition to broader data sharing, they predicted that the advancement of geospatial technologies, particularly GPS, satellite imaging and the Internet, would enable aid agencies to improve the efficiency of their programs – even in remote, inhospitable regions [34]. Noting trends like the declining cost of imagery and availability of highly-accurate topographic maps, Kavanagh and Home listed a variety of potential GIS-based applications:

1. coordination of relief and transport;
2. mitigation of economic and environmental impact of sudden or large-scale migrations;
3. selection of refugee camp locations;
4. evaluation of local water, food and fuel supplies;
5. analysis of risk;

6. Communication with donors with maps showing relief statistics, refugee movements, areas of hostility, etc.

That 1999 forecast was updated by a 2005 study of how remote sensing, GIS and GPS were being used in Complex Humanitarian Emergencies (CHEs). It draws upon case studies and trends in technological advancement to propose the following potential geospatial applications:

1. Cartography (land use, infrastructure mapping, demography, logistics, etc.)
2. Media / Communications (status reporting, program assessment, etc.)
3. Crisis Simulation (mission rehearsal, migration patterning, contingency planning, etc.)
4. Environmental Planning (crop cultivation, resource assessment, etc.)
5. Hazard Management (seismic analysis, camp location planning, flood mitigation, etc.)
6. Vulnerability Assessment (early warning systems for famine, epidemics, tsunami, etc)
7. Risk Reduction ("hotspots" identification, mitigation programming, etc.)
8. Organizational Management (efficiency improvement, financial analysis, training, etc.) [3]

2.5 Yemen Situation overview

Table 2.2 Yemen Humanitarian Response Plan 2012: Key parameters

2012 Yemen Humanitarian Response Plan: Key parameters	
Duration	12 months (Jan-Dec 2012)
Key milestones in 2012	• School year (Sept-May) • Migration to south coast (Jan-April, Sept-Dec) • Migration to west coast (Jan-Dec) • Planting: June-July & Dec • Harvest: March-April, Oct-Dec • Floods: Feb, April-May, Aug-Oct, Dec • Storms: March • Drought: June
Target beneficiaries	• 2,057,000 severely food-insecure • 407,203 IDPs • 116,830 conflict-affected • 140,000 returnees • 169,885 refugees & asylum seekers; 26,000 migrants • 466,337 under-five girls and boys affected by acute malnutrition • 339,280 small- and medium-scale farmers

Yemen is facing a complex emergency that includes widespread conflict-driven displacement and a slow-onset crisis in food security, malnutrition and outbreak of communicable diseases, particularly water-borne diseases. In the north, the vast majority of long-term internally displaced people (IDPs) displaced by six rounds of conflict in Sa'ada remain in displacement due to fears of insecurity, damaged homes, a lack of livelihood opportunities and poor basic services. In the south, recent fighting between security forces and insurgents has additionally displaced nearly 90,000[1] people. The influx of migrants, refugees and asylum-seekers from the Horn of Africa continues, driven by conflict and famine. Civil unrest, in some instances involving high levels of violence, has severely disrupted the delivery of basic social services, exacerbating widespread and chronic vulnerabilities. Weak

[1] According to the latest official figures from UNHCR and the Government's IDP Executive Unit, as of 31 August 2011, 89,084 IDPs have been registered in the southern governorates of Yemen.

economic growth, a growing trade deficit, and an unstable national currency have exposed the population to rising global food and fuel prices. A delayed political settlement to the current stalemate could trigger further conflict across the country which would only deepen the humanitarian crisis.

In response, the Humanitarian Country Team (HCT) intends a more comprehensive humanitarian response beyond the current focus primarily on IDPs and conflict-affected people in the north and south. Efforts must expand to include both non-displaced and non-conflict-affected populations in acute humanitarian need across the country. The HCT is requesting US$247 million to respond to nearly four million target beneficiaries spread across the country. This is still only 44% of the total population in need, whose numbers are expected to significantly rise during 2012. The funding requirements are 95% over 2011's original requirements, and 54% over the requirements as revised during the Mid-Year Review, reflecting the expansion of needs and the higher costs associated with delivering aid (e.g. insecurity, fuel prices).

The HCT has agreed to five key objectives: to (1) conduct assessments that identify vulnerable populations; (2) identify and implement appropriate responses; (3) increase focus on protection and advocacy for vulnerable populations; (4) ensure that preparedness and capacity-building effectively

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[2]All dollar signs in this document denote United States dollars. Funding for this appeal should be reported to the Financial Tracking Service (FTS, fts@un.org), which will display its requirements and funding on the current appeals page.

respond to humanitarian needs; and (5) strengthen community resilience and recovery. Humanitarian early recovery and development interface across the country, where possible, will be a prominent component of this Yemen Humanitarian Response Plan. The HCT will also explore alternative means to deliver assistance within the existing security situation, building on modalities that have proved effective in Yemen and elsewhere, including remote management and working through local partners.

Many communities facing acute needs are wholly reliant upon humanitarian aid. Recent malnutrition data in the north and south of the country indicate rates are at crisis levels, with global acute malnutrition rates well above the emergency threshold. Without adequate intervention, there is a risk that the north could slide into severe food insecurity. Similarly, due to disruption in routine vaccination programmes, there is a risk that deadly but preventable diseases such as polio will re-emerge. Water, sanitation and hygiene assistance remains critical to provide communities with safe, clean water and sanitation facilities, and to combat the risk of acute watery diarrhoea and cholera. Protection concerns are also mounting, including those related to the use of child soldiers by many armed groups. Sustained and expanded humanitarian action across the country is critical.

2.5.1 Yemen Priority Needs

1. Food: high food prices are a determining factor of household food insecurity (97% of poor rural households are net food buyers).

2. Health: vulnerability to disease outbreaks (diarrhoea, cholera, polio, measles). Shortages of fuel/electricity threaten the cold chain. Abyan: breakdown in public health services.

3. Shelter & NFI: Yahees: IDPs living in communal caves affected by sporadic bombing. Bab-Al Sabah: IDPs living in collective centres with limited privacy/security. South: 35% of households require NFIs.

4. Nutrition: very high malnutrition rates for children under five reported in northern governorates and worrying rises in conflict and displacement-affected southern regions.

5. WASH: three million people are at immediate public health risks due to poor WASH facilities and services. Water-borne diarrhoeal cases led to 58% malnutrition amongst children in the north and on-going outbreaks in the south killed 107, of whom 25% children. Options are limited (water trucking three times more expensive than a year ago).

6. Protection: Conflict areas: grave child rights violations, landmines, risk of detention, forced recruitment and reprisals, recruitment of child soldiers, particularly by Al-Houthi, Govt. forces/pro-govt militias and extremist groups. Sana'a: insecurity, extensive land mines, damage to property, fear of arrest, detention. High risk of physical abuse for stranded migrants.

7. Agriculture & Livelihoods: fuel shortages affecting irrigation, transportation to markets and livelihoods exacerbating negative coping strategies. 46.5% food insecurity in Raymah, Hajja, Ibb and Amran.

8. Education: difficult access due to lack of documentation, overcrowding and/or school buildings used by IDPs. Incidents of occupation of schools by militants in both northern and southern governorates.

2.5.2 Yemen Trend Analysis

Violence has continued across the country since early June. Sana'a: marked expansion of hostilities. Abyan: fighting has led to an influx of IDPs to Aden and Lahj; Jaar and Zinjibar towns in Abyan are under the influence of Islamic militants. North: ceasefire between the Al Houthis and Government forces is loosely holding.

Continued displacement is expected in southern governorates for the next one to three years due to on-going fighting between the Government and Islamists. Return for the majority of IDPs is unlikely in the next 6-12 months.

Considerable deterioration in the socio-economic situation over the last six months exacerbated by political stalemate, general governmental malaise, rising food prices and a critical energy shortage, most likely forcing millions of Yemenis deeper into poverty, hunger and malnutrition.

Fuel prices have stabilised yet prices of basic commodities remain very high. Food prices increased on average 40% (Jan-Sep). High food prices, combined with unemployment have led to an increase in negative coping strategies.

Sharp increase in killing, injuries, use & recruitment/number of children drafted into armed conflict. Increase in violence, exploitation of children, and levels of distress. UXO causing injury and death, and increased child drop-out from schools, child labour, child trafficking and early marriage as a result of hardship and poverty.

Increase in shelter needs in northern governorates expected due to winter, while tension increases between 20,000 IDPs occupying 80 schools in Aden and host communities. In November 1,754 IDPs face forced eviction from schools, no shelter solution identified yet by Government.

Increase in water-borne diseases due poor WASH practices/sanitation facilities.

Increase in immigration from the Horn of Africa to over-stretched transit centres.

Expected increase in gender-based violence in southern governorates. Also increased number of cases of psycho-social trauma.

2.5.3 Additional basic humanitarian and development indicators for Yemen

Table 2.3 Additional basic humanitarian	Most recent data	Previous data or	Trend *

and development indicators for Yemen			pre-crisis baseline (not older than 2000)	
Economic status	Gross national income per capita	• $2,350 (PPP 2009) • $1,070 (2009) (World Bank: Key Development Data & Statistics)	$1,750 (PPP 2000) $410 (2000)	
	Percentage of population living on less than $1 per day	17.5% (UNDP HDR, 2011)	5.1% (UNDP HDR, 2000)	
	Percentage of population who live under the national poverty line	• 34.8% average • 20.7% in urban areas • 40.1% in rural areas (Household Budget Survey, 2005/2006)	n/a	
Health	Number of health workforce per 10,000 population	10 /10,000 (WHO, Global Health Observatory 2004)	n/a	
	Infant mortality rate (0-1 year)	57 per 1,000 live births (UNICEF, 2010)	51 per 1,000 live births (UNICEF, 2009)	
Food Security	IFPRI Global Hunger Index, 2011	25.4 Alarming	29.2 Alarming (Global Hunger Index, 2003)	
	Percentage of food-insecure people	31.5% (WFP CFSS, 2010)	N/A	
Education	Enrolment in primary education	• Boys: 85%, girls: 65% (UNICEF Yemen at a glance, 2003 – 2008) • Boys: 79%, girls: 66% (UNESCO Institute for Statistics, 2008) • Boys: 85%, girls: 70% (UNESCO Institute for Statistics, 2010)		n/a
	Percentage of boys and girls of primary school age out of school	Boys: 20%, girls: 34%, total: 27% (UNESCO Institute for Statistics, 2008)		n/a
Child Protection	Child labour (% aged 5–14 years)	Total:23%, urban: 21%, rural:24% (UNICEF, MICS, 2006)		n/a
	Child marriage (% of women aged 20-24 years who were married or in union before their 18th birthday)	Total: 32% urban: 28%, rural: 35% (MICS 2006)		n/a
	Birth registration rate for children under five	Total: 22%, urban:38%: rural;16% (MICS 2006)		n/a

Please note that UNICEF figures are also based on figures from the Inter-agency Group for Child Mortality Estimation, composed of UNICEF, WHO, UN Population Division and the World Bank.

Trends	improving	stable	worsening

2.6 Summary

A review of the literature surrounding GIS-based coordination of humanitarian assistance leads to several interesting conclusions. First, the field has struggled to attract a disciplined, scholarly level of research, and progress to date has been sporadic and unsystematic at best. Second, the humanitarian community has not established a rich doctrine of information sharing through peer-reviewed journals: indeed, there are few high-quality forums for the exchange of best practices, and knowledge distribution primarily occurs through personal relationships or institutional affiliations as opposed to the formation of widely-respected professional standards, (with perhaps the exception of public health applications of GIS-based analysis, which has rapidly advanced due to its rich tradition of peer-reviewed research). Third, there is little obsession amongst the humanitarian community for technology-based solutions. Even when one disregards issues of cost-benefit and sustainability of technocentric information management, civilian organizations are the polar opposite of military organizations, like NATO, in their reluctance to depend upon high technology solutions at a tactical (i.e. field) or even a strategic (i.e. headquarters) level. Fourth, the introduction of GIS-based analysis needs to respect the humanitarian community's fiercely independent, technology-weary character. This may change over time, but there is much work to do in developing better standards of information management and data sharing before it will be realistic to propose highly integrated, GIS-driven coordination systems like those used by military planners to manage complex, multi-unit operations. And finally, the utility of GIS-based coordination of humanitarian response will be negligible if it doesn't embrace important priorities after most disasters. These include:

- rapid provision of adequate quality and quantities of drinking water;
- swift construction of effective sanitation facilities;
- maintenance of minimum levels of food energy intake using either local or imported sources;
- supply of housing and clothing, or financial aid for their purchase, and
- delivery of emergency medical care, particularly prevention of infectious diseases.

The above list, extracted from Anthony Redmond's 2005 paper in the British Medical Journal [76], stresses the importance of a needs-based, standards-compliant approach to responding to international emergencies. Obviously the above list is not comprehensive or applicable to every emergency: the provision of security is a very high priority and should also be added when working within complex emergencies. And rapid deployment of international search and rescue teams might also need to be added, as they can be a helpful (albeit over-glorified) form of assistance after some types of natural disasters [76]. In any situation, once the initial relief phase has transitioned to recovery, a broad range of sustainable development priorities begin to apply, such as ensuring that the recovery process is reinforced by mitigation against and preparedness for future disasters.

The ultimate objective of GIS-based humanitarian coordination, and therefore of this research, is to maximize the situational awareness of all responders so that aid priorities can be established and then collectively achieved. The remaining sections detail the goals and questions of this research, and method in which it was conducted.

Chapter 3 - Research Methodology and Procedures

3.1 Research Sequence

This research is based upon a five-phase sequential exploratory design mixed methods approach. Figure 3.1 below illustrates the core activity sequence:

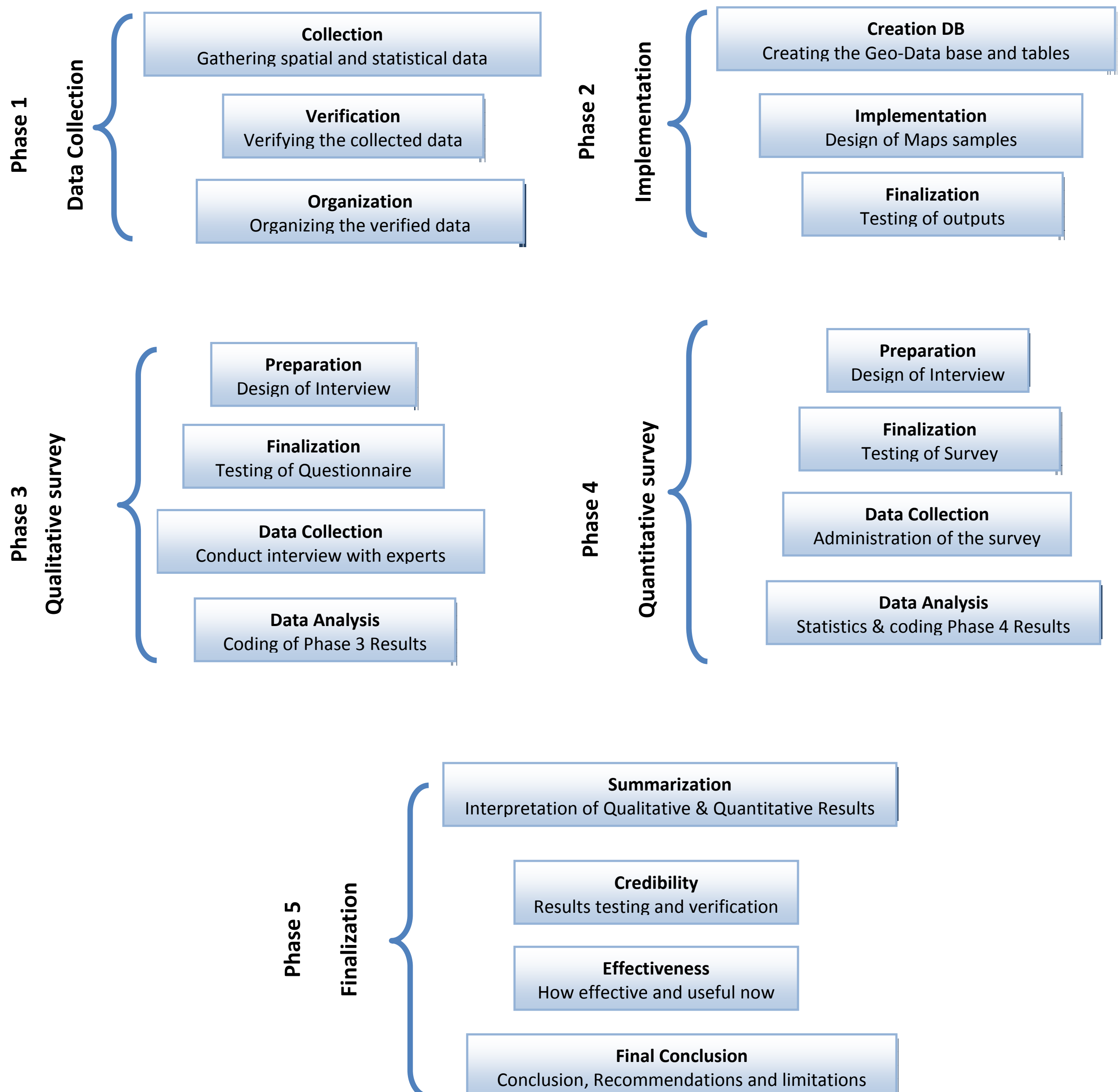


Figure 3.1 Core Research Method Sequence

The first phase of the sequential exploratory research method is the starting point because it contains and reforms the spatial and statistical data which is necessary for creating the visual samples in the second phase.

The second phase of the sequential exploratory research method is the experimental or practical part of this method where the researcher creates the visual maps in order to support the surveys of the third and fourth phases.

Although Creswell indicates that priority is generally given to the third phase of the sequential exploratory research method, this study placed equal or greater emphasis on the fourth phase of the research sequence. [77] Indeed, the third phase was undertaken in order to create a sound basis upon which to conduct the fourth phase of research, with the hope of testing the alternate questions correctly: if the application of GIS-based analysis for humanitarian coordination was already well-defined, the third phase would not have been necessary – it would have been sufficient to simply conduct a user survey of known, operational applications of GIS-based analysis. Creswell is quite right, nevertheless, in arguing that the sequential exploratory method is best suited for understanding unfamiliar phenomena; for this study, the necessity for third and fourth phases of data collection and analysis is predicated by the infancy of GIS-based coordination of humanitarian assistance. The last phase of the sequential exploratory research method is describing the final steps and the conclusions

In totality, the research method involved the following primary tasks:

1. Comprehensive review of academic literature relevant to the application of GIS-based spatial analysis to coordinating humanitarian assistance;

2. Classification and description of principle types of GIS-based analysis – this task included a review of industry trends (see Section 1.3) and best practices as they apply to humanitarian assistance;

3. Design of expert interview questionnaire, and acquisition of GWU Internal Review Board and OCHA approvals;

4. Administration of Phase 3 interviews amongst domain experts within the United Nations, governmental and non-governmental organizations, private sector and academia.

5. Design of representative case studies for each category of GIS-based analysis, based upon hypothetical and actual data obtained during recent UN deployments;

6. Refinement of case studies based upon Phase 3 interviews;

7. Design of user survey, and acquisition of GWU Internal Review Board and OCHA approvals;

8. Administration of survey amongst a statistically-representative population of mid-to-senior level decision makers in the humanitarian organizations involved in recent UN-led humanitarian interventions;

9. Aggregation and generation of descriptive and inferential statistical analysis of survey results;

10. Conclusions of overall utility of spatial analysis to humanitarian assistance within the boundary conditions described in Section 3.2, and

11. Preparation, submission and final defense of thesis.

3.2 Research Method Procedures

In this part of Chapter 3, the researcher will explain the mechanism and activities which have been conducted to complete the phases 1 and 2 of the sequential exploratory research method.

3.2.1 Data Collection (Phase 1)

3.2.1.1 Collection

Gathering data is always difficult especially in such unstable and economic circumstances in Yemen because of many reasons like:

1. Weak understanding of information sharing
2. Many unreliable source

The advantage of researcher works with UNOCHA was an assist to collect the necessary data from governmental and international sources.

The data was collected in different electronic format depending on the source; the collected data mainly was not only very helpful in terms of organization work in Yemen at the same time but also to support research method.

An example of the collected data attached to this thesis as Appendix C

The collected data and its format

1. Spatial Data
    a. Administrative boundaries of Yemen (3 levels, Governorate, District and Subdistrict) (vector data for ArcGIS as Layer format-Shape files *.dbf, *.sbx, *.shp, *.shx)

Attributes of Gov_pol

OBJECTID_1 *	Shape *	OBJECTID	Governorat	Governor_1	Governor_2	Shape_Leng	Shape_Length	Shape_Area
1	Polygon	1	11	Ibb	إب	4.251901	4.251901	0.447471
2	Polygon	2	12	Abyan	أبين	6.874566	6.874566	1.374608
3	Polygon	3	13	Amanat Al Asimah	أمانة العاصمة	1.185789	1.185789	0.032862
4	Polygon	4	14	Al Bayda	البيضاء	5.148447	5.148447	0.777632
5	Polygon	5	16	Al Jawf	الجوف	8.089313	8.089313	3.347671
6	Polygon	6	18	Al Hudaydah	الحديدة	11.944669	11.944669	1.112331
7	Polygon	7	30	Al Dhale'e	الضالع	2.885645	2.885645	0.334479
8	Polygon	8	27	Al Mahwit	المحويت	2.184284	2.184284	0.195982
9	Polygon	9	28	Al Maharah	المهرة	11.310834	11.310834	5.637428
10	Polygon	10	15	Taizz	تعز	5.590986	5.590986	0.83554
11	Polygon	11	17	Hajjah	حجة	5.745926	5.745926	0.701564
12	Polygon	12	19	Hadramaut	حضرموت	23.671139	23.671139	14.106457
13	Polygon	13	20	Dhamar	ذمار	5.211088	5.211088	0.636705
14	Polygon	14	31	Raymah	ريمة	1.810828	1.810828	0.158963
15	Polygon	15	21	Shabwah	شبوة	10.295873	10.295873	3.271935
16	Polygon	16	22	Sa'ada	صعدة	5.686738	5.686738	1.050298
17	Polygon	17	23	Sana'a	صنعاء	7.462016	7.462016	1.002618
18	Polygon	18	24	Aden	عدن	2.67369	2.67369	0.06243
19	Polygon	19	29	Amran	عمران	4.308835	4.308835	0.667846
20	Polygon	20	25	Lahj	لحج	7.126994	7.126994	1.05528
21	Polygon	21	26	Marib	مأرب	7.99937	7.99937	1.473037

Figure 3.2 Example of Yemen Administrative boundaries data

    b. Yemen Topography (vector data for ArcGIS as Layer format-Shape files *.dbf, *.sbx, *.shp, *.shx)

Attributes of Contours1000m

FID	Shape	VALUE_	MEANING	HEIGHT	Shape_Leng	Shape_Area
114	Polygon	4	3000 - 7000 feet	7000	0.133549	0.000417
115	Polygon	4	3000 - 7000 feet	7000	0.071176	0.000198
116	Polygon	5	7000 - 11000 fee	9000	0.041199	0.000096
117	Polygon	4	3000 - 7000 feet	7000	0.049012	0.000089
118	Polygon	4	3000 - 7000 feet	7000	0.070854	0.000262
119	Polygon	4	3000 - 7000 feet	4000	0.071711	0.000204
120	Polygon	4	3000 - 7000 feet	6000	0.886534	0.003415
121	Polygon	5	7000 - 11000 fee	9000	0.059739	0.000149
122	Polygon	4	3000 - 7000 feet	7000	0.032091	0.000048
123	Polygon	4	3000 - 7000 feet	7000	0.02773	0.000043
124	Polygon	4	3000 - 7000 feet	7000	0.177553	0.000733
125	Polygon	4	3000 - 7000 feet	7000	0.036217	0.000069
126	Polygon	5	7000 - 11000 fee	9000	1.133175	0.00759
127	Polygon	4	3000 - 7000 feet	4000	0.058764	0.00018
128	Polygon	4	3000 - 7000 feet	7000	0.041805	0.000114
129	Polygon	5	7000 - 11000 fee	8000	0.033792	0.000075
130	Polygon	4	3000 - 7000 feet	7000	0.033201	0.000044
131	Polygon	4	3000 - 7000 feet	4000	0.075199	0.000221
132	Polygon	4	3000 - 7000 feet	7000	0.064277	0.000139
133	Polygon	5	7000 - 11000 fee	8000	0.0305	0.000065
134	Polygon	4	3000 - 7000 feet	7000	0.501926	0.003287
135	Polygon	4	3000 - 7000 feet	7000	0.140971	0.000489
136	Polygon	4	3000 - 7000 feet	7000	0.037502	0.000057
137	Polygon	5	7000 - 11000 fee	8000	0.040211	0.000101
138	Polygon	5	7000 - 11000 fee	10000	0.084702	0.000188
139	Polygon	4	3000 - 7000 feet	7000	0.80007	0.004286
140	Polygon	4	3000 - 7000 feet	7000	0.036449	0.000057
141	Polygon	4	3000 - 7000 feet	7000	0.051588	0.000087
142	Polygon	4	3000 - 7000 feet	7000	0.038685	0.000085
143	Polygon	4	3000 - 7000 feet	4000	0.038078	0.000101
144	Polygon	4	3000 - 7000 feet	7000	0.042684	0.000083
145	Polygon	4	3000 - 7000 feet	4000	0.075999	0.000258
146	Polygon	4	3000 - 7000 feet	7000	0.027103	0.000032
147	Polygon	5	7000 - 11000 fee	8000	0.065522	0.000217
148	Polygon	4	3000 - 7000 feet	5000	0.031723	0.00007
149	Polygon	4	3000 - 7000 feet	7000	0.069017	0.00012
150	Polygon	4	3000 - 7000 feet	7000	0.066553	0.000112
151	Polygon	4	3000 - 7000 feet	6000	0.07848	0.000222
152	Polygon	5	7000 - 11000 fee	9000	0.057107	0.000194
153	Polygon	4	3000 - 7000 feet	7000	0.040051	0.000055
154	Polygon	5	7000 - 11000 fee	8000	0.038841	0.000085
155	Polygon	4	3000 - 7000 feet	4000	0.038966	0.00011
156	Polygon	5	7000 - 11000 fee	8000	0.040675	0.000098

Record: 1 Show: All Selected Records (0 out of 1516 Selected

Figure 3.3 Example of Yemen Topography data

c. Yemen Roads map (vector data for ArcGIS as Layer format- Shape files *.dbf, *.sbx, *.shp, *.shx)

Attributes of Roads

FID	Shape *	LAYER	OBJECTID	TYPE	Shape_Leng	Roadname
0	Polyline	Unpaved Road	1	Unpaved Road	0.15288	
1	Polyline	Unpaved Road	2	Unpaved Road	0.017008	
2	Polyline	Unpaved Road	3	Unpaved Road	0.851454	
3	Polyline	Unpaved Road	4	Unpaved Road	0.082147	
4	Polyline	Unpaved Road	5	Unpaved Road	0.643165	
5	Polyline	Unpaved Road	6	Unpaved Road	0.097503	
6	Polyline	Unpaved Road	7	Unpaved Road	0.233788	
7	Polyline	Unpaved Road	8	Unpaved Road	0.002363	
8	Polyline	Unpaved Road	9	Unpaved Road	0.053542	
9	Polyline	Unknown Line Type	10	Asphalt Road	0.263513	
10	Polyline	Unpaved Road	11	Unpaved Road	0.177517	
11	Polyline	Unpaved Road	12	Unpaved Road	0.035263	
12	Polyline	Unpaved Road	13	Unpaved Road	0.03647	
13	Polyline	Unpaved Road	14	Unpaved Road	0.092398	
14	Polyline	Unpaved Road	15	Unpaved Road	0.071813	
15	Polyline	Unpaved Road	16	Unpaved Road	0.06996	
16	Polyline	Unpaved Road	17	Unpaved Road	0.136539	
17	Polyline	Unpaved Road	18	Unpaved Road	0.136381	
18	Polyline	Unpaved Road	19	Unpaved Road	0.248814	
19	Polyline	Unpaved Road	20	Unpaved Road	0.209781	
20	Polyline	Unpaved Road	21	Unpaved Road	0.055384	
21	Polyline	Unpaved Road	22	Unpaved Road	0.120843	
22	Polyline	Unpaved Road	23	Unpaved Road	0.343344	
23	Polyline	Unpaved Road	24	Unpaved Road	0.407295	
24	Polyline	Unpaved Road	25	Unpaved Road	0.324385	
25	Polyline	Unpaved Road	26	Unpaved Road	0.217815	
26	Polyline	Unpaved Road	27	Unpaved Road	0.1484	
27	Polyline	Unpaved Road	28	Unpaved Road	0.181121	
28	Polyline	Unpaved Road	29	Unpaved Road	0	
29	Polyline	Unpaved Road	30	Unpaved Road	0.000215	
30	Polyline	Unpaved Road	31	Unpaved Road	0.241492	
31	Polyline	Unpaved Road	32	Unpaved Road	0.324788	
32	Polyline	Unpaved Road	33	Unpaved Road	0.206141	
33	Polyline	Unpaved Road	34	Unpaved Road	0.090393	
34	Polyline	Unpaved Road	35	Unpaved Road	0.047739	
35	Polyline	Unpaved Road	36	Unpaved Road	0.073819	
36	Polyline	Unpaved Road	37	Unpaved Road	0.074251	
37	Polyline	Unpaved Road	38	Unpaved Road	0.186586	
38	Polyline	Unpaved Road	39	Unpaved Road	0.086719	
39	Polyline	Unpaved Road	40	Unpaved Road	0.145354	
40	Polyline	Unpaved Road	41	Unpaved Road	0.127991	
41	Polyline	Unpaved Road	42	Unpaved Road	0.111617	
42	Polyline	Unpaved Road	43	Unpaved Road	0.145786	

Record: 1 Show: All Selected Records (0 out of 5296 Selected)

Figure 3.4 Example of Yemen Roads data

d. Yemen Health Facilities data (vector data for ArcGIS as Layer format- Shape files *.dbf, *.sbx, *.shp, *.shx)

Attributes of health

FacilityID	id_gov	id_dist	id_facil	arab_nam	eng_nam	type_facil	owner_faci	urban_faci	accom_faci	Year
130001	13	1306	130001	???? ??????? ???????? ???? ?????		Health Center/Clinic	Cooperative	Urban		1998
150001	15	1502	150001	????? ????? ?????? ??????? ???????		Hospital	Government	Urban		1998
150002	15	1514	150002					Rural		1998
270001	27	2706	270001	???? ???? ??? ????? ????		Health Unit	Cooperative	Rural	Inside Building	1998
240001	24	2403	240001	???? ??? ?? ????? ???? ?????? ????????		Health Center/Clinic		Urban		1998
280001	28	2804	280001	?????? ?????? ???????		Hospital	Government	Urban	Outside Building	1998
280002	28	2807	280002	???????? ?????? ?????		Rural Hospital	Government	Urban	Outside Building	1998
280003	28	2808	280003	???????? ?????? ???		Rural Hospital	Government	Urban	Outside Building	1998
190001	19	1918	190001	?????? ?????		Rural Hospital	Government	Rural	Other	1998
280004	28	2803	280004	???????? ?????? ???		Rural Hospital	Government	Urban	Outside Building	1998
110001	11	1101	110001	?????? ????? ???? ?????		Health Center/Clinic	Private	Urban		1998
110002	11	1101	110002	?????? ?????? ??? ?????		Health Unit	Private	Rural		1998
110003	11	1101	110003	?????? ?????? ?????		Health Unit	Private	Rural		1998
110004	11	1101	110004	?????? ????? ??? ????		Health Center/Clinic	Government	Rural		1998
110005	11	1101	110005	?????? ?????? ?????????		Health Unit	Government	Rural		1998
110006	11	1101	110006	?????? ?????? ??? ???		Health Unit	Government	Rural		1998
110007	11	1101	110007	?????? ?????? ??????		Health Unit	International AID	Rural		1998
110008	11	1101	110008	?????? ?????? ???????		Health Unit	Government	Rural		1998
110009	11	1101	110009	?????? ????? ??? ????		Health Center/Clinic	Government	Rural		1998
110010	11	1101	110010	?????? ?????? ???????		Health Unit	Government	Rural		1998
110011	11	1102	110011	?????? ???? ????		Hospital	Government	Urban		1998
110012	11	1102	110012	?????? ????? ??? ???		Health Center/Clinic	Government	Rural	Outside Building	1998
110013	11	1102	110013	?????? ????? ?????		Health Center/Clinic	Government	Rural		1998
110014	11	1103	110014	?????? ????? ???????		Health Center/Clinic	Government	Urban		1998
110015	11	1103	110015	?????? ?????? ??????		Health Unit	Cooperative	Rural		1998
110016	11	1103	110016	?????? ?????? ???????		Health Unit	Cooperative	Rural		1998
110017	11	1103	110017	?????? ?????? ??? ????		Health Unit	Private	Rural	Inside Building	1998
110018	11	1104	110018	?????? ????? ???? ?????		Health Center/Clinic	Government	Rural		1998
110019	11	1104	110019	?????? ?????? ???? ??????		Health Unit	International AID	Rural		1998
110020	11	1104	110020	?????? ?????? ??????		Health Unit	International AID	Rural		2001
110021	11	1104	110021	?????? ?????? ?????? ???????		Health Unit	Cooperative	Rural		1998
110022	11	1104	110022	???? ?????? ????????		Health Center/Clinic	Government	Rural		1998
110023	11	1104	110023	?????? ?????? ??? ????		Health Unit	Cooperative	Rural		1998
110024	11	1105	110024	?????? ????? ???????		Health Center/Clinic	International AID	Rural		1998
110025	11	1106	110025	?????? ?????? ??? ?????????		Hospital	Government	Urban	Outside Building	1998
110026	11	1106	110026	?????? ????? ?????		Health Center/Clinic	Cooperative	Rural		1998
110027	11	1106	110027	?????? ?????? ???????		Health Unit	Cooperative	Rural		1998
110028	11	1106	110028	?????? ????? ??? ????		Health Center/Clinic	Private	Rural		1998
110029	11	1106	110029	?????? ????? ??? ??????		Health Center/Clinic	Cooperative	Rural		1998
110030	11	1106	110030	?????? ?????? ??? ?????		Health Unit	Government	Rural		1998
110031	11	1107	110031	?????? ????? ???????		Health Center/Clinic	Government	Rural		1998
110032	11	1107	110032	?????? ?????? ???? ??????		Health Unit	Government	Rural		1998

Record: 1 Show: All Selected Records (0 out of 2705 Selected) Options

Figure 3.5 Example of Yemen Health Facilities data

2. Statistical Data (Data available in Excel and PDF format)

a. The General Population Housing and Establishment Census2004

b. Administrative Divisions

c. Indicators of Poverty

d. Vital Statistics

e. Labour Force

f. Construction & Building & Housing

g. Education

h. Health

3.2.1.2 Verification

This is very important research procedure in order to have credible results and trusted outputs.

The researcher here has to the data verifications through some indicators for example the reliability of the source of information and comparison with other sources.

Raster & Vector Data Validation: Development of the case studies required a validation of the geospatial data to ensure it supports the required analysis. This was a preliminary step intended to confirm that available data would allow each type of analysis to be assessed. When data deficiencies were identified, a decision was made to search elsewhere for the required data or substitute actual data with synthetic data that better demonstrated the category of GIS-based analysis.

3.2.1.3 Organization

After the completion of data verification process, the data format should be organized in a specific shape or format depends on the software we are using, in this thesis the researcher is using the famous GIS application ArcGIS 9.3 from ESRI .

The structure of the collected data mentioned in the section 3.2.1.1 was changed into the required ArcGIS format in order to be ready for farther processes.

3.2.2 Implementation (Phase 2)

The phase 2 or the practical part (it can be called also as experimental part) in the thesis is focusing on creating the databases, which in the GIS application known as geodatabases.

The concept of database management should be implemented in order to create the database structure (Tables and Relations). It also possible to create the database in platforms like MS SQL, MS Access, Oracle or even as simple excel file.

After reforming the data collected in phase 1 into the right format which is in this case it calls shape file or layer or GeoDatabase. We start creating the maps according to the purpose or criteria.

In the surveys of phase 3 and 4 some of maps produced to support the understanding the research goal and survey significance.

Here following some examples of visualizing the data on map;

Figure 3.6 Map of Yemen Administrative boundaries

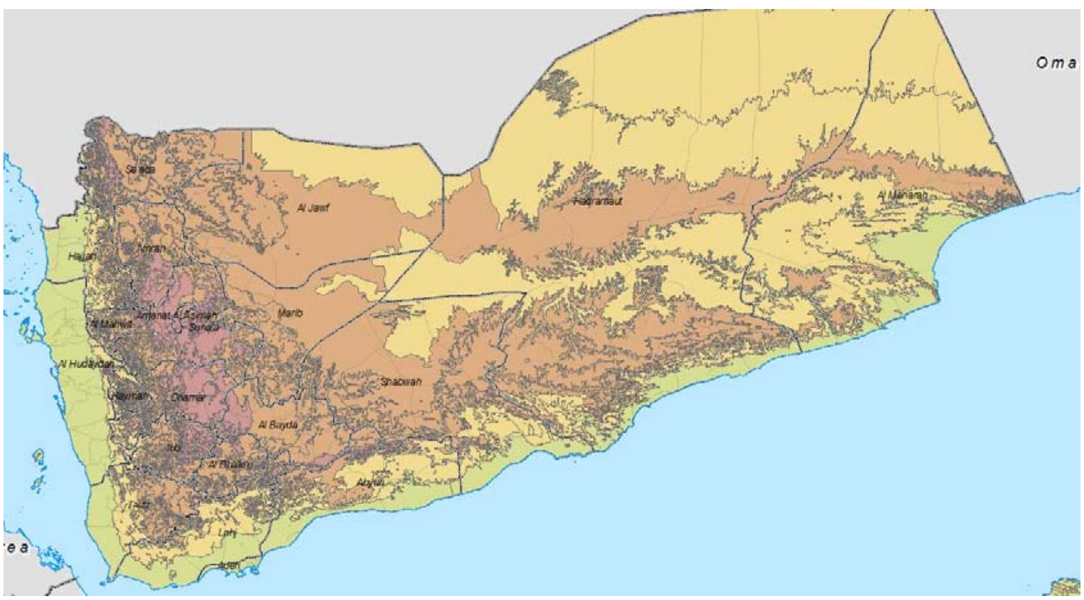


Figure 3.7 Map of Yemen Topography

Figure 3.8 Map of Yemen Roads

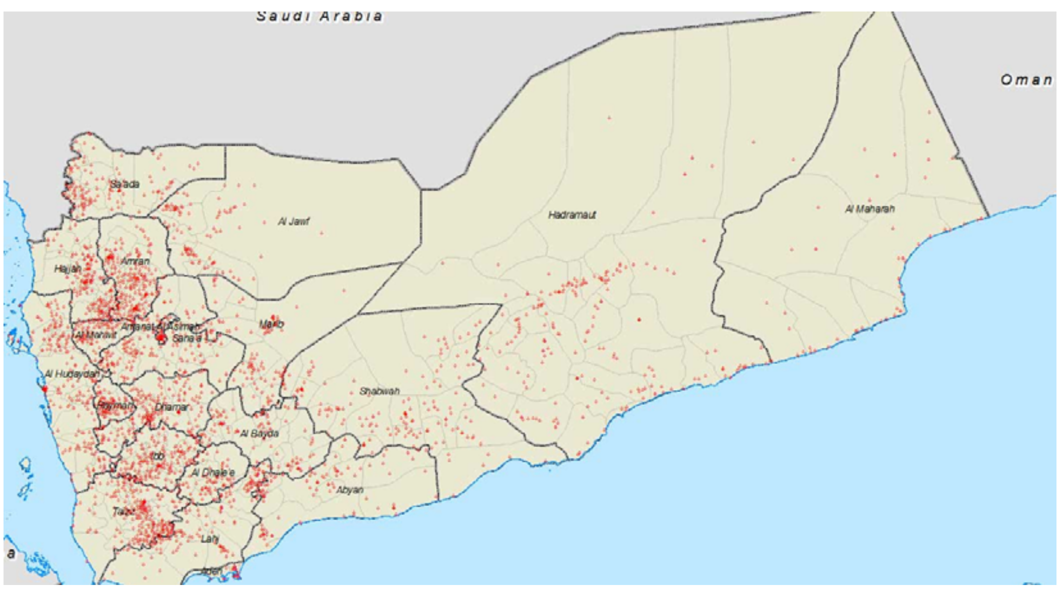


Figure 3.9 Map of Health Facilities in Yemen

Phases 3 of the research method will be discussed in the chapter 4 and phase 4 will have detailed explanation in chapter 5.

Phase 5 of the sequential exploratory research method is represented fully in chapter six of this thesis.

3.3 General Analysis Procedures

The utility assessment involved the following data analysis procedures:

1. Expert Interview Qualitative Data Analysis: Interviews were structured but open-ended, and identified the most likely applications of GIS-based analysis for humanitarian coordination. In addition to generating applications, the interviews produced a list of qualitative elements of utility such as analytical difficulty, data availability, impact on decision-making, etc. This aggregated dataset, described in Chapter 4, was then coded and summarized in order to identify the most promising applications of GIS-based analysis to test during the user survey.

2. User Survey Statistical Analysis: An intensive, international user survey was conducted to test the research questions, and elicit opinions and guidance from mid- to senior-level humanitarian decision makers within and outside of the UN agencies. The analysis of survey results was necessary to produce a statistically-representative depiction of how useful each type of analysis is to humanitarian operations at a field and headquarters level.

3. Overall Utility Assessment: Based upon the expert interviews and the user survey statistics, the final analytical procedure was to assess the overall utility of GIS-based analysis. This was derived from the survey results, since it is the users and beneficiaries of coordination services that have the right to determine utility. That final assessment of utility was calculated in the form *"x% of the humanitarian community finds analysis type A to be beneficial within a confidence level of y and within a confidence interval of z"*.

In conclusion, it is important to observe that the above research method is an original approach specifically engineered to assess the utility of information that is relevant but not widely-available amongst a target audience. Indeed, it was on the speculation that there might be types of GIS-based analysis that could have a decisive impact on the coordination of humanitarian assistance, that the above research method was designed. Had GIS-based analysis already been widely-understood and used within the humanitarian community, a simple quantitative of user opinion would probably have been sufficient. However, in the absence of broad user awareness, it was crucial to engineer a mixed method of research that captured both theoretical and field-tested opinion that could inform a reliable conclusion of overall utility.

Chapter 4 – Qualitative Research and Data Analysis

4.1 Introduction

Between March, 2011, and April, 2012, interviews with a total of 30 domain experts were conducted in order to identify the most likely types of spatial analysis that could have a decisive impact in the coordination of humanitarian operations. Although the literature review was informative, the paucity of credible references to the "state of the art" in humanitarian applications of Geographic Information Systems made a systematic analysis of expert opinion essential, particularly before attempting to determine whether GIS-based analysis was useful to mid-to-senior level decision makers involved in providing humanitarian assistance.

One or more representatives based on Yemen from each of the organizations mentioned on the table 4.1 were invited and agreed to participate in the survey** :

Table 4.1 Qualitative Survey Participants

Type	Organization
Governmental	National Information Center
	Central Statistical Organization
	IDPs Executive Unit
	Ministry of Public Health & Population
	Ministry of Telecommunication and Information Technology
Donors	USAID
	DFID
	ECHO
UN Agencies	UN Office for the Coordination of Humanitarian Affairs (OCHA),
	United Nation Development Program (UNDP)
	UNICEF
	UNHCR
	WFP
	WHO

International NGO	Save the Children
	CARE
	ADRA
	Islamic relief
	INGOF
Local NGO	Yemen Humanitarian Forum
	CSSW
	SOUL
	Al-Saleh Foundation
	YDN
Academia/Research	Sana'a University
	Aden University
	Studies and Researches Center
Private Sector	NATCO
	MTN

** All names withheld as per regulations pertaining to human research.

4.2 Interview Method & Format

The interviews mentioned on the section 4.1 took a total of 2200 minutes (36.6 hours), or an average of 55 minutes per individual, and were conducted primarily by individual interview.

Candidates were selected because of their familiarity with the coordination of humanitarian assistance, the application of GIS during humanitarian operations, and their ability to knowledgeably and accurately reflect the decision making interests of humanitarian community at large.

Prior to conducting each interview, candidates were provided an executive summary of the thesis topic and research goals at least 48 hours in advance, in order to allow them to prepare for the discussion. Most acknowledged that they found this pre-reading very helpful in formatting their thoughts and ideas prior to their actual interviews.

At the start of each interview, the researcher reviewed the objectives of the study and the process that would be followed. Participants were also informed that their comments would be aggregated and de-identified, to ensure that they felt comfortable in expressing themselves without fear of repercussion. This automatically minimized any propensity for interviewees to express themselves in the hope for personal attribution, which was a welcome side-effect.

Since the GIS training and professional expertise of each participant varied, the researcher adopted an open-ended interview technique that was customized around those issues most familiar to the interviewee. Nevertheless, certain common questions were asked to initiate each conversation and center the dialogue around the research objectives. These questions included:

1. What has been your organization's experience with the UNOCHA information products? Have you found their core GIS products and services helpful? Why or why not?
2. Is your organization using GIS for data analysis to support decision making at the field, regional or headquarters level? If so, what forms of GIS-based analysis are being used, and how are they effective?
3. Beyond cartography, do you believe that GIS can be used to support the coordination of humanitarian assistance given resource limitations (skill,

time, data, etc) common during most emergencies? If yes, how so and why? If no, why not?

4. If headquarters and field-level decision makers in your organizations were provided, during the initial and advanced stages of a humanitarian operation, with Who-What-Where (3W) information contained within a Geovisualization tool like Google Earth, would that make the 3W information more useful to them? Would they be able to understand relief activity information (and associated gaps in relief distribution) more easily than with the current 3W reports that are provided in spreadsheet or static PDF format?
5. GIS transportation networks facilitate point and route optimization, however they require significant development and maintenance in order to be effective. Can you imagine any emergency situation where that investment could be justifiable if it resulted in improved navigation, location optimization and long-term development planning?
6. What applications of GIS-based analysis do you think would be most useful in the coordination of humanitarian assistance? What are the key questions that humanitarian professionals have during the initial and later stages of response? These and other questions generated a wide array of responses, opinions and suggestions, summarized in the next section.

4.3 Summary of the qualitative results

4.3.1 Potential Applications of GIS-based Analysis

The following applications for GIS-based analysis to support the coordination of humanitarian assistance were suggested during the Phase 3 expert interviews:

1. Optimize site selection of refugee camps based upon security, resource availability and accessibility;

2. Estimate population of those affected by an emergency, and model their migrations in relation to events, risk, ethnicities, religions, tribal affiliations, political conditions, etc.;

3. Substantiate UN Flash Appeal and Consolidated Appeals Process with more quantitative and geographical analysis, and better use of historical databases, statistical modeling, and gap analysis;

4. Conduct Gap Analysis within a GIS using an international standard for units of measurement, such as the ICRC standards for assessing needs and relief activity:

5. Estimate the impact of Unexploded Ordnance (UXO) on populations, livelihoods, education, health, etc.;

6. Optimize distribution of humanitarian services in relation to affected populations, in order to maximize accessibility to shelter, health, education, etc. infrastructure – this would be a regular process to reflect dynamics, such as the migration of populations, the addition or loss of infrastructure, etc.;

7. Analyze human vulnerability at the camp-level, to protect women and children from violence or exploitation;

8. Perform "pseudo-urban planning" for long-term refugee settlements (eg. Almazrak Camps - Haradh, Yemen) – this could improve the delivery of humanitarian services and the efficiency of camp design, while still respecting the constraint that refugee settlements are a technically a "temporary solution", even if they last for decades;

9. Perform anonymous agent modeling, especially once data is validated and organized efficiently;

10. Enable queries of Who-What-Where (3W), Survey of Surveys (S2), Gap Analysis, and cluster-specific reports within a Geovisualization client, so that any organization can produce highly-customized analysis using public data overlaid with its own data;

11. Facilitate orientation and mission rehearsal for humanitarian activities in unfamiliar regions;

12. Conduct “What if” analysis to predict impact of seasonal weather patterns on response operations;

13. Facilitate site selection of relief hubs and shelters using centroid analysis as well as resource/risk assessment - this could become a core analytical product, particularly if it exploited UNEP environmental sensitivity datasets, with land use, terrain, resource potential, logistics, etc;

14. Support route optimization since the first question after a rapid onset emergency is “How do we reach the victims quickly?”;

15. Estimate the extent and severity of disaster impact, to anticipate location and volume of casualties based upon location and type of emergency;

16. Predict areas that may be impacted due to domino effects and cascading failures in response coordination - Gap Analysis of deteriorating response capacities may be included with this type of analysis;

17. Report the facts on the ground neutrally and diplomatically, to advocate local and international policy making: one potential application might be to analyze UXO contamination in Abyan Governorate – such analysis would make a powerful case that the |Internally displaced persons can return back safely to their homes.

18. Extend Gap Analysis to include not just needs or activities, but also

"organizational capacity", such as type, number and skill of staff, organizational expertise (by sector), organizational behavior (structures and support systems), overlaid with funding priorities;

19. Complement standard Monitoring & Evaluation (M&E) tools (e.g. Logical-Frameworks, etc.) with GIS-based analysis, particularly geostatistics, in order to assess spatial efficiency and efficacy of donor-funded projects; and,

20. Conduct damage assessments showing percentage and quantity of housing stock damage, infrastructural functionality, morbidity/mortality. While this is a data collection problem before it becomes an analytical problem, cluster sampling techniques could allow rapid extrapolation of damage assessments, which are more accurate than the simplistic approach currently used (for example, the damage impact of the wars in the northern and southern parts of Yemen are typically estimated by drawing concentric circles around the damaged areas)

4.3.2 Overall Themes of Opinion and Concern

In addition to the above suggestions, the Phase 3 interviewees provided a generous amount of feedback about the state of affairs in humanitarian coordination and the application of GIS. The repetition of certain themes reveals a consensus of opinion within the humanitarian community that is insightful and relevant to the main research question.

The Table4.2 lists the most common themes of opinion and concern that emerged during the Phase 3 interviews. The right-hand column indicates the number of participants who iterated each theme

Table 4.2 Qualitative Survey Thematic Summary

Common Themes	Repetitions
Data sharing is limited due to a lack of convenient sharing mechanisms	15
Geovisualization has begun to release the potential of GIS for analysis & communication	15
There aren't enough reliable base layers (administrative, gazetteer, etc.) to perform even rudimentary analysis or cartography in some situations.	11
Data sharing is limited due to concerns about autonomy, power, lack of reciprocity, security concerns	10
There is no time, skill or interest in doing "fancy" GIS-based analysis in the field	10
Gap Analysis is the most urgent application of GIS in coordinating response	9
Because highly sophisticated analysis is the least compelling for decision makers, GIS-based analysis must be easily understandable and intuitive to non-technical managers.	9
Poor data quality during humanitarian operations limits more sophisticated applications	7
Decision makers want analytical support but don't know what to ask for – therefore demand must be generated through academic-private-public sector partnerships, pilot projects, *ad hoc* initiatives, and field-driven advocacy	7
Coordination needs to begin immediately after a disaster, not 3-4 weeks later	6
Donors won't fund GIS data collection, modeling, symbology and analysis	6
Don't introduce new tools, analytical products and services after a disaster – engender GIS-based analysis throughout the disaster-development continuum	5
Advanced forms of analysis should be done by rear support teams, not on the front-lines by overwhelmed HIC staff	5
GIS-based analysis is very client-specific: generic analysis serves nobody well, and cluster-specific analysis can't be done by OCHA	4
Advice and information is welcomed by humanitarian agencies, but only if it is non-compulsory and without obligation	3
Analysis should drive coordination, not just passively report what has happened.	3
Coordination information is too perishable to enable GIS-based analysis to be sufficiently reliable	2

For experienced humanitarian professionals, many of the themes listed in Table 4.2 are familiar, but their frequency of iteration and enduring persistence suggest that there are fundamental and structural challenges to the flow of humanitarian information that need to be addressed if the full potential of GIS-based analysis is to be realized.

Finally, the themes in Table 4.2 only capture research data that fell within the scope of the main research question regarding utility. The remainder of the data was peripheral or unrelated to the assessment of utility of GIS-based analysis, and was not analyzed.[††]

†† The raw data for each interview is de-identified and aggregated before analysis. Any data excluded from this Chapter was considered irrelevant to testing the alternate hypotheses, however it may still be meaningful for future research related to the coordination of humanitarian assistance and humanitarian information management.

4.3.3 Suggestions for Further Research

Many Phase 3 interviewees offered comments or presented problems that, even if inconsequential to testing this researcher's questions should be recognized as opportunities for further research. The following problems and research questions are proposed for future study:

1. Needs assessment surveys are often abandoned before completion, and take too long to design, conduct, aggregate and ultimately inform humanitarian decision making. Also, excessive and redundant surveying of disaster victims is often worsened by the failure of survey teams to follow-through on promises to share the results of their survey with the participants. How can rapid assessments produce more actionable information and restore participant confidence? Also, how can standard rapid assessments be modularized so that they are adaptable for different types of emergencies and don't need to be custom-designed every time there is an emergency?

2. Monitoring & evaluation of relief projects rarely investigate if coordination actually made a difference – there is only anecdotal evidence that HICs significantly affect how relief organizations conduct their operations in the field. Do coordination activities (3W, S2, maps, analysis, meetings, portals, emails, etc.) significantly reduce the amount of morbidity and mortality following an emergency, and ultimately improve the provision of humanitarian assistance?

3. Many argue that without reliable data, it is not possible to produce reliable maps or analysis. Others argue that waiting for "perfect data" is unnecessary – approximation is good enough given the overall imprecision of humanitarian operations. Is crude estimation of P-Codes, village populations, roads and other base layers sufficient for GIS applications, or is bad information worse than no information?

4. It would appear that many base layers for GIS-based analysis are available in advance of an emergency: georeferenced data about health, utilities, lines of communication, response capacity, coordination mechanisms, demography, hazard zones, etc., often exist within host government, donors or development partners, but is not organized or centralized. How much of the data requirements for relief coordination could be collected in advance, for countries that are disaster-prone or on the verge of an emergency?

5. Nobody has attempted to link situational awareness with field reporting mechanisms, as a means to promote data sharing and Gap Analysis. Can the HIC web portal enable a field worker to quickly update his/her organization's activities while querying 3W info (perhaps all within a Geovisualization tool)?

6. A major challenge to efficient coordination of humanitarian operations is the difficulty for NGOs, UN agencies and governments to report their activities in a timely and systematic way.
7. Another major challenge to the coordination of humanitarian assistance is integrating less experienced local responders with the more experienced international responders; UN and INGO staff typically arrive on the scene of an emergency with pre-existing relationships and a professional dialect that can be quite intimidating and discriminatory to the participation of local responders. How can humanitarian coordination more effectively include local NGOs and non-conventional relief needs and activities? Also, how can "organizational capacity" be assessed in order to plot the strengths & weaknesses of the overall response picture?

The above suggestions for future research are not necessarily being proposed for the first time – many interviewees inferred that the need to address these issues has been recognized for some time – but it is helpful to see them listed together, to clearly establish what experts believe are the priorities for the advancement of this field.

4.4 Analysis of Results

As one can see from reading Section 4.3, the research data collected during the Phase 3 expert interviews provides a rich set of commentary from which to conduct this and other related research. It is important to note that the Phase 1 interviews included both GIS optimists and sceptics, who had a wide range of suggestions and opinions about the state of humanitarian assistance coordination. While their comments differed tremendously, the interviewees seemed to share consensus with regards to three crucial issues:

1. Gap Analysis, which is the comparison between Assessed Needs and actual Relief Provision (3W), is the most urgent priority in humanitarian coordination. Whether GIS is used to facilitate this or not, there was an unequivocal call by the interviewees for Gap Analysis to be embraced as the principal means to improve the coordination of humanitarian assistance.
2. Data sharing, at least at the field-level, is not so much an issue of information control as it is problem of limited resources. This negates the commonly-recited excuse that data sharing is constrained because of fears of surrendering organizational independence or strategic advantage. While that may be a concern at the headquarters level, at the field level decision makers need easy sharing mechanisms that do not add to their burden of activity and that provide a favorable return on investment. Humanitarian agencies would probably participate if inter-agency data sharing mechanisms informed every participant's internal decision making, and did not create additional work for

overwhelmed humanitarian workers.

3. GIS must not be promoted as a solution in itself, but as a tool that supports fundamental improvements in the humanitarian coordination system. Even the most energetic supporters of GIS felt that cartographic or analytical applications needed to be simple, easily comprehendible, reliably reproducible, and grounded in sound management practices. The unanimous (i.e. both technophobes and technophiles) insistence that GIS be employed only when it can provide unique and decisive intelligence implies that even the next generation of technology-savvy humanitarian worker will expect a compelling advantage if s/he is going to devote resources towards GIS.
4. In parallel to these three overarching points of agreement, there were a range of differing suggestions with regards to the application of GIS-based analysis to support the coordination of humanitarian assistance. Section 4.3.1 contained a summary of these suggestions, which in most cases are in reality a combination of GIS-based analyses. In order to convert these proposed applications into specific examples, which could then be tested in Phase 4 of this study, it was necessary to weigh them against the points of consensus above and the researcher's own convictions and intuition. This iterative process resulted in the following list of GIS-based analyses, which reflect the most relevant and representative applications for each category of analysis proposed in Section 1.2

Table 4.3 Derived List of Applications of GIS-Based Analysis

Category of GIS-based Analysis	Suggested Application
Queries & Measurements	• **Gap Analysis**: Calculation of actual or percentage of relief needs met over time • **Measurement**: Computation of distance or area of various lines or polygons of interest • **Range Analysis**: Determine population within or beyond some distance of certain humanitarian services • **Zone Analysis**: Calculate total relief capacity within a certain area, and/or compliance with humanitarian standards
Transformations	• **Vulnerability Estimation**: Anticipate most vulnerable populations based upon proximity to hazard(s) and distance from relief distribution infrastructure • **Site Selection**: Identify potential locations for humanitarian services given certain terrain, land use and proximity criteria
Optimizations	• **Service Optimization**: Determine best locations for humanitarian services given a transportation network • **Route Optimization**: Calculate the shortest or fastest route between two or more locations
Geostatistics	• **Central Feature Analysis**: Compute the most central (i.e. median) point amongst a set of points • **Exact Center Analysis (Weighted):** Compute the center of a set of weighted points (i.e. mean) • **Cluster Analysis**: Detect the correlation of a set of points with one another, and underlying phenomena
Geovisualization	• **Orientation & Situation Reporting**: Communicate the response environment and humanitarian activity through Geovisualization
Hypothesis Testing	• **"What If?" Analysis**: Simulate the impact of a change to one or more variables that affect humanitarian operations

This list of potential applications informed the design and development of the survey used to conduct Phase 4 of this thesis, and was the desired and essential output from Phase 3. Of course there are many more potential applications of GIS that apply one or more categories of analysis, but for the purposes of determining utility, the researcher concluded that the above list provided a representative and plausible set of scenarios that could be tested within the context of a user survey.

A final remark regarding the Phase 3 interview results: notwithstanding the list of potential analytical applications presented in Section 4.3.1, it was surprisingly challenging to extract ideas of how the coordination of humanitarian assistance could be improved using GIS-based analysis *even amongst GIS specialists*. Cartographic applications clearly dominate the imagination of both technical and non-technical decision makers, and only a few of the interviewees were able to articulate specific analytical applications of GIS without the researcher's assistance. This does not reveal a malaise within the humanitarian community, but it does validate Chapter 2's assertion that humanitarian professionals are far less dependent upon GIS to inform their decision making than their counterparts concerned with environmental conservation, development, or public health.

Chapter 5 – Quantitative Research and Data Analysis

5.1 Introduction

As explained in Chapter 4, the sequential exploratory method involves the use of a qualitative research phase followed by a quantitative research phase. Once the collection and analysis of the Phase 3 expert interview data was completed (see Chapter 4), it was possible to begin the second phase of this thesis: a survey of the humanitarian community at-large.

Voluntary, surveys are inherently prone to bias, since they attract participants who are interested in the topic being investigated – obviously, individuals disinterested in the topic of humanitarian coordination or GIS could not be expected to participate. Section 6.4 addresses any concern that the reader may have regarding the fact that the survey only represented the "GIS-interested" portion of the total population of mid-to-senior level decision makers within the humanitarian community. First, however, this Section describes the method, format and aggregated results of the survey.

5.2 Survey Method & Format

Appendices A and B exhibit the invitation, introduction and survey employed to collect the Phase 4 research data. The invitation was sent via email to approximately 200 individuals involved in recent humanitarian emergencies, randomly selected from a variety of sources including contact databases provided by the United Nations, the researcher's professional network, and public directories of humanitarian organizations and their staff. The email encouraged recipients to forward the invitation to any others whom they thought should also participate, and the survey was open to anyone without restriction. Those invitees interested in the survey attached in the email invitation, in addition to some basic information about the survey, the introduction ensured that prospective participants were informed of their rights as voluntary participants, in accordance to the policies applicable to all of The St Clements University based on Sana'a-Yemen. The survey contained 27 questions listed on twenty successive pages. No personal data was collected, all questions were voluntary, and participants were not requested to provide any information that might compromise their anonymity.

The first five questions requested basic metadata about the participant, such as his/her professional role, location, and experience in humanitarian assistance. Questions 6 through 12 then requested participants to grade their interest, knowledge and dependency of GIS, and to disclose any expectations they had regarding the ability for GIS to have a decisive impact on the coordination of humanitarian assistance. The remaining survey questions requested them to rate, using a closed-ended, modified Likert Scale, their opinion of how useful thirteen applications of GIS-based analysis (see Table 4.3) would be to them. For each application, survey participants were given a short description and example and then asked "how useful is this type of analysis to you? They had the following response choices: (1) Not useful, (2) Somewhat useful, (3) Very useful, (4) Essential, and (5) I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me).

The researcher made a deliberate and repeated effort to urge the participants not to rate *the example* of each type of analysis, but to rate the type of analysis itself and to consider how it might be ideally applied to support their typical decision making. Participants were also requested to elaborate on how each type of analysis might be applied to their specific context using an open-text field, before moving on to the next type of analysis.

Before reviewing the survey's results, it is important to acknowledge that there is an inherent risk to surveying a phenomenon not widely-understood: the majority of respondents were, in fact, asked to speculate upon the usefulness of forms of analysis which they had never operationally used or (most likely) even previously considered. In order to reduce the obvious limitation in conducting such an assessment, the researcher avoided the use of technical terms in the survey, and developed each case study using context and language as recognizable as possible to humanitarian professionals with little to no familiarity with GIS-based analysis.

5.3 Summary of Results

The survey was conducted between March 1- May 30, 2012. As summarized in the table below, 200 individuals participated in the survey, 137 individuals completed the survey form successfully, 56 individuals not responded to the survey and 7 forms eliminated because of the error of finishing the survey. Survey participants required a median average of 30 minutes to complete the survey.

Table 5.1 Quantitative Survey Completion Statistics

# of Invitations	200
# of eliminated forms	7
# of no response	56
# of Respondents (who completed the survey)	137
Median Completion Time	30 minutes

5.3.1 Participant Profile – General Demographics

The first five questions of the survey collected basic demographic data about the respondents. As indicated below, the sample population included participants with a variety of experience, responsibility, as well as thematic and geographic focus; while it is not certain whether the sample population is a perfect representation of the humanitarian community at-large, the researcher would argue that it is a reliable representation of the population most likely to consider using GIS-based analysis to inform their decision making processes.

Question 1. What type of organization do you work for?

Exactly one-third of the respondents worked for an international NGO, nearly the same number who worked for the United Nations. The remainder of those surveyed was employed within government or academia, or with a donor institution, domestic NGO, Red Cross/Red Crescent society, or some other agency.

Table 5.2 Survey Participants – Organizational Affiliation

Type of Organization	**# of Respondents**	**%**
United Nations	63	46%
Non-Governmental (International)	23	17%
Government	19	14%
Non-Governmental (National)	15	11%
Academic / Research	6	4%
Donor Agency	5	4%
Private Sector / Consulting	4	3%
Other	2	1%
Total	**137**	**100%**

2. What is your primary role/responsibility in your organization?

The most common job category of the survey respondents was “Program Manager”, a broad classification which typically involves significant decision making influence at a field or “tactical” level during an emergency. The second largest groups were “Technicians”, followed by “Senior Manager/Policy Maker”. The survey made no attempt to define these categories since they are familiar to most humanitarian professionals. There was also no specific attempt to rank these categories in terms of decision making influence, however it is clear that the survey captured the opinions of all of the main (potential) user groups of GIS-based analysis.

Table 5.3 Survey Participants - Occupation

Primary Role/Responsibility	# of Respondents	%
Program Manager	33	24%
Technician	26	19%
Senior Manager / Policy Maker	17	12%
Relief Worker	15	11%
Desk Officer / Analyst	13	9%
Researcher	9	7%
Monitoring & Evaluation	7	5%
Other	6	4%
Consultant	6	4%
Communications & Public Relations	3	2%
Donor Development / Management	2	1%
Total	137	100%

Question 3. What is the geographic focus of your work in Yemen? (select all that apply)

Question 3 asked the respondents to select the geographical regions which they considered to be the foci of their work in Yemen. The table below shows the regional breakdown: Areas of Conflict in Yemen in general was the most common geographical focus, no doubt because of the concentration of humanitarian activity underway in Yemen (after 6 wars with Alhouthies), Southern part (in response to the crisis of 2011 political changes and youth revolution), and All Governorates (in response to the economic deterioration and increase of poverty level).

Table 5.4 Survey Participants - Geographic Focus

Geographic Focus	# of Respondents	%
All Governorates	55	40%
Northern Part	62	45%
Southern Part	58	42%
Central Part	41	30%
Areas of Conflicts	66	48%
Areas of Natural Disasters	15	11%
Other	23	17%
Total (respondents were allowed multiple selections)	137	100

Survey participants provided 281 responses in total, and were able to select as many regions as they wished to. Fifty five respondents selected all of the geographic regions, indicating that their interests were completely global. However the majority selected just two or three regions, resulting in an average of about 2-3 geographic regions per survey respondent.

Question 4. Which humanitarian cluster(s) best describe your primary area(s) of activity? (Select no more than 3)

Having established geographical areas of interest, the researcher then attempted to understand the thematic areas of interest of the survey respondents. Most of the survey participants were able to define their thematic specializations within the Global Cluster definitions of the Inter-Agency Standing Committee. Survey respondents could select up to three choices but, on average, opted for roughly two choices out of the total of 10 provided (9 Clusters categories plus an open-ended “Other” category).

Table 5.5 Survey Participants - Humanitarian Cluster Thematic Focus

Thematic Focus	# of Respondents	%
Food	70	51%
Protection	61	45%
Nutrition	53	39%
(WASH) Water & Sanitation	48	35%
Health	43	31%
Other (Miscellaneous)	29	21%
Education	25	18%
Camp Management /Emergency Shelter	19	14%
Other (Relief)	17	12%
Early Recovery	11	8%
Cluster Coordination	3	2%
Total (respondents were allowed up to 3 selections)	137	100

Once basic metadata had been collected about each survey participant, Questions 5 through 12 attempted to gather the respondents' background in, dependency upon, and opinion about, GIS. This was essential to test the researcher's expectation that the survey would attract participants interested or involved in humanitarian applications of GIS, and to calibrate the expertise being harnessed to evaluate the utility of GIS-based analysis in the main section of the survey.

Question 5. How many years of experience do you have within the field of humanitarian assistance?

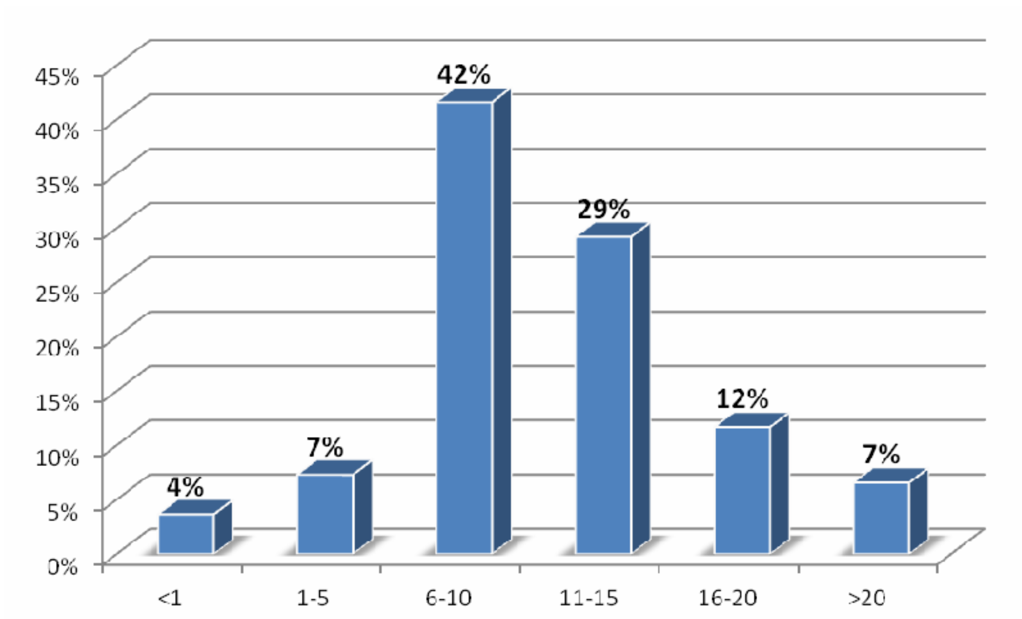


Figure 5.1 Survey Participants - Years of Experience

Nearly 42% of the survey respondents had more than five years and less than ten years of applicable experience, and almost 48% had more than ten years of experience. The participation of both young and seasoned humanitarian professionals was reassuring since coordination decisions are made at varying levels of seniority. Although the research questions are tested without weighing respondents differently, section 6.4 provides the utility scores for the entire group, and for those with more than 6 years of experience, for comparison purposes.

Questions 6 to 12 attempted to build on the basic demographic information that has already been collected, to develop a more nuanced impression of each survey participant's views and comprehension of GIS.

Question 6. How would you rate your expectations (i.e. interest) in the Humanitarian applications of Geographic Information Systems (GIS)?

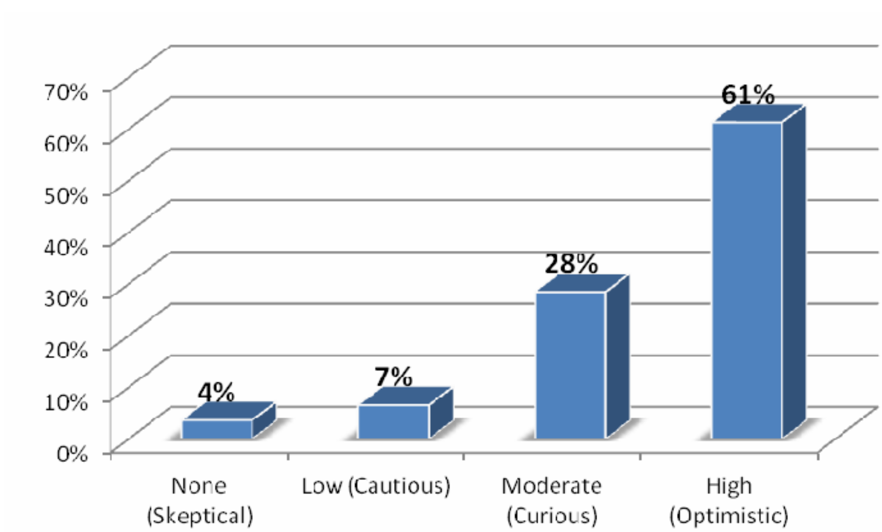


Figure 5.2 Survey Participants - GIS Expectations

As expected, the survey participants were indubitably interested in the subject of humanitarian applications of GIS, as illustrated by the figure above. Less than 11% of the respondents stated that they were either cautious or sceptical about GIS. Since the survey sample probably exaggerates the proportion of GIS optimists amongst the humanitarian community, no attempt is made to extrapolate the survey's findings across the community at-large: only that segment of the population reflected by the survey.

Question 7. How would you rate your understanding of GIS?

Having established their level of interest, the researcher then ask the respondents to rate their understanding of GIS. Nearly two-thirds felt they had a basic-to-good understanding of the topic, whilst less than 17% admitted to having a poor understanding of GIS.

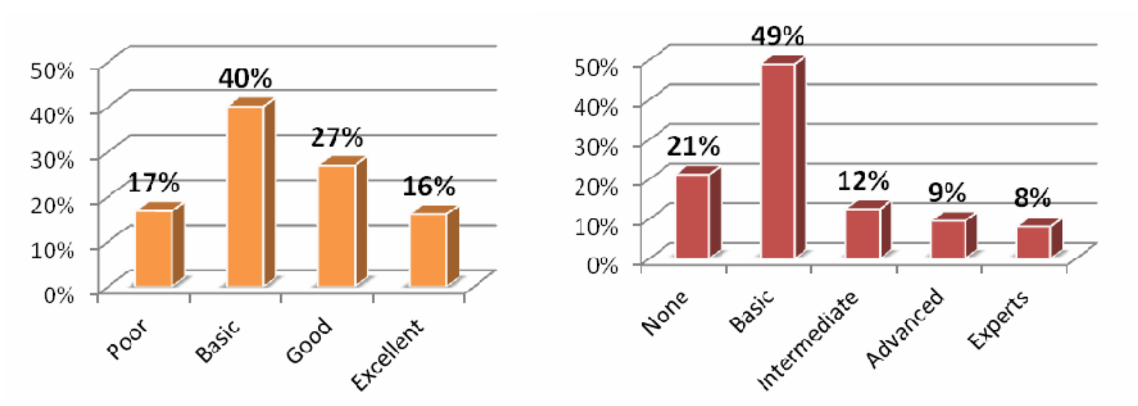


Figure 5.3 Survey Participants - Understanding and Training in GIS

Question 8. How would you rate your level of training in GIS?

Curiously, when asked about their level of training, respondents were slightly more modest, with half of the 137 surveyed declaring that they had either basic or no training in GIS. Weak comprehension of the analytical potential of GIS appears prevalent amongst the humanitarian community – in fact, the researcher observed during the expert interviews that even those with "GIS" in their job title were most comfortable with the cartographic applications of GIS and data management issues, not the analytical applications of GIS. The figures above compare these relative levels of understanding and training. While not inconsistent, they do suggest that those surveyed may have an exaggerated level of confidence about their GIS knowledge, or have obtained their understanding through self-study and hands-on experience, and not formal training

Question 9. How often do you use or depend upon GIS during humanitarian emergencies?

The frequency that respondents use GIS during emergencies is helpful in determining their dependency as decision makers, either for its cartographic or analytical application. Nearly 50% of the respondents admitted to having little to no dependency upon GIS. Only 9% of those surveyed, even amongst such an enthusiastic group, could be described as "operationally dependent" on GIS.

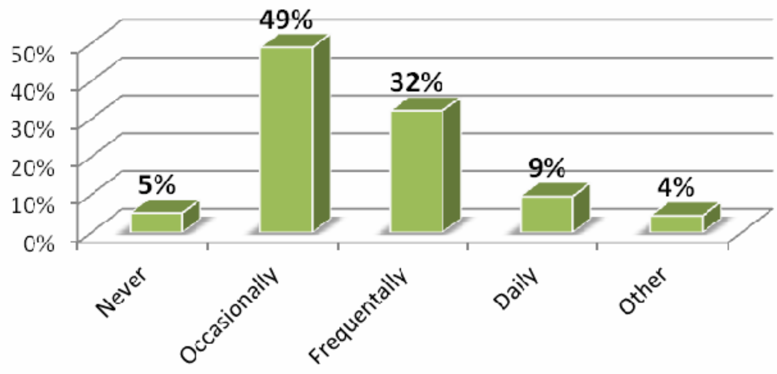


Figure 5.4 Survey Participants – GIS Dependency

Question 10. What sources of GIS products and/or services do you use during humanitarian emergencies?

There a variety of sources from which to obtain GIS products or services. Basic orientation and thematic maps are provided at little to no cost by UN and non-UN agencies, under formal or informal arrangements to share geographic information through public portals like UNOCHA's and ReliefWeb site.

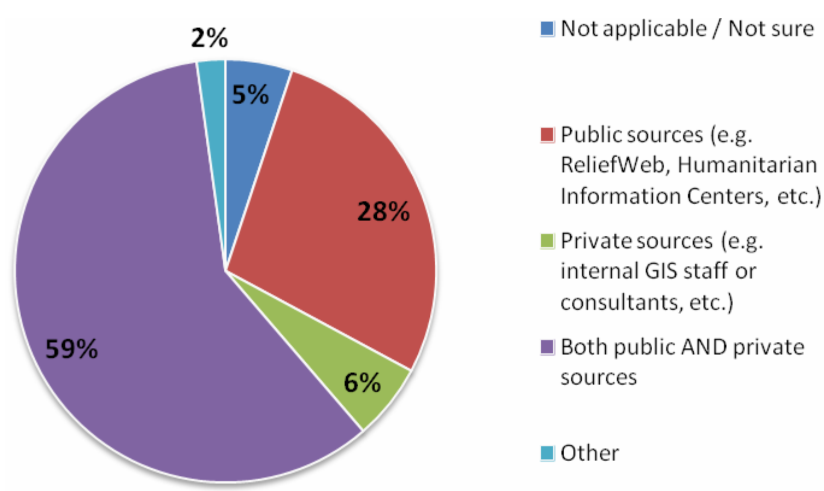


Figure 5.5 Survey Participants - Sources of GIS Products & Services

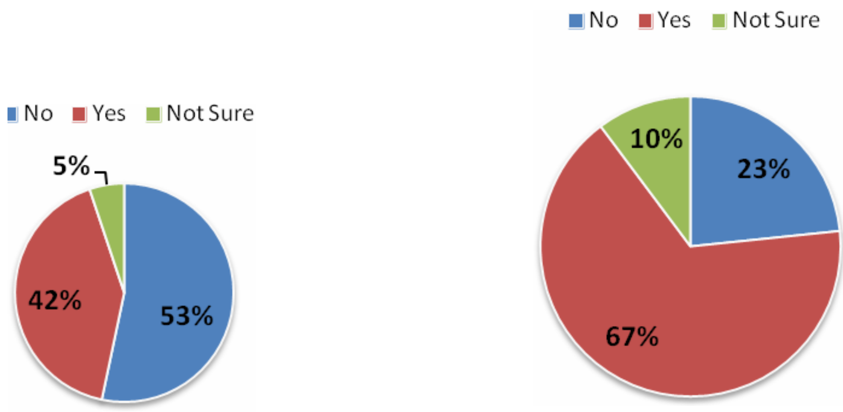
Approximately 28% of survey respondents said they rely exclusively on public sources for GIS. Another 6% exclusively used private sources, such as staff and consultants skilled in targeting the precise decision making needs of those organizations. Impressively, over half of the survey respondents exploited both public and private sources of GIS during humanitarian emergencies, indicating that generic and customized applications were used in combination by most decision makers. About 7% of those surveyed did not use GIS or were unsure of the sources used, or provided responses inconsistent with the question.

Question 11. Do you believe that GIS currently has a decisive impact upon the international coordination of humanitarian assistance?

Before undertaking an assessment of the utility of GIS-based analysis, it seemed appropriate to understand how the survey participants viewed the overall utility of GIS within the context of humanitarian coordination. A large minority (41%) felt that it currently had a decisive impact. The remaining 59% of respondents who were unconvinced of the impact on the humanitarian decision making, were then asked a follow-up question:

Question 13. Even if it may not currently, do you believe that GIS could have a decisive impact upon the coordination of humanitarian assistance (in the future)?

Nearly three-quarters of those who felt that GIS did not *currently* have a decisive impact believed that it could in the future. Only seven of the 156 people surveyed felt that GIS does not, and could not, have a decisive impact on the coordination of humanitarian assistance.



Currently

Future

Figure 5.6 Survey Participants - Views of GIS Impact upon Coordination

Having collected sufficient information about the participants, the survey then proceeded with the utility assessment. Questions 13 through to 26 elicited the survey participants' opinions of how useful GIS-based analysis would be to them during humanitarian emergencies. Each GIS application tested was based upon the findings of Phase 1 expert interviews as being the most representative of each category of analysis when applied to the coordination of humanitarian assistance (see Table 5.3). An obvious survey limitation was the need to convey, in some cases, fairly complex analytical processes to many individuals with limited theoretical and applied understanding of GIS. Therefore, the researcher provided the respondents with the option of not having to rank usefulness if they felt uncomfortable or unclear with any particular application – this appeared to minimize contamination of the utility scores with "forced" responses. As a final cross-check, Question 27 requested participants to select the top five types of analysis to validate their responses. They then had an opportunity to provide another comments or suggestions before completing the survey.

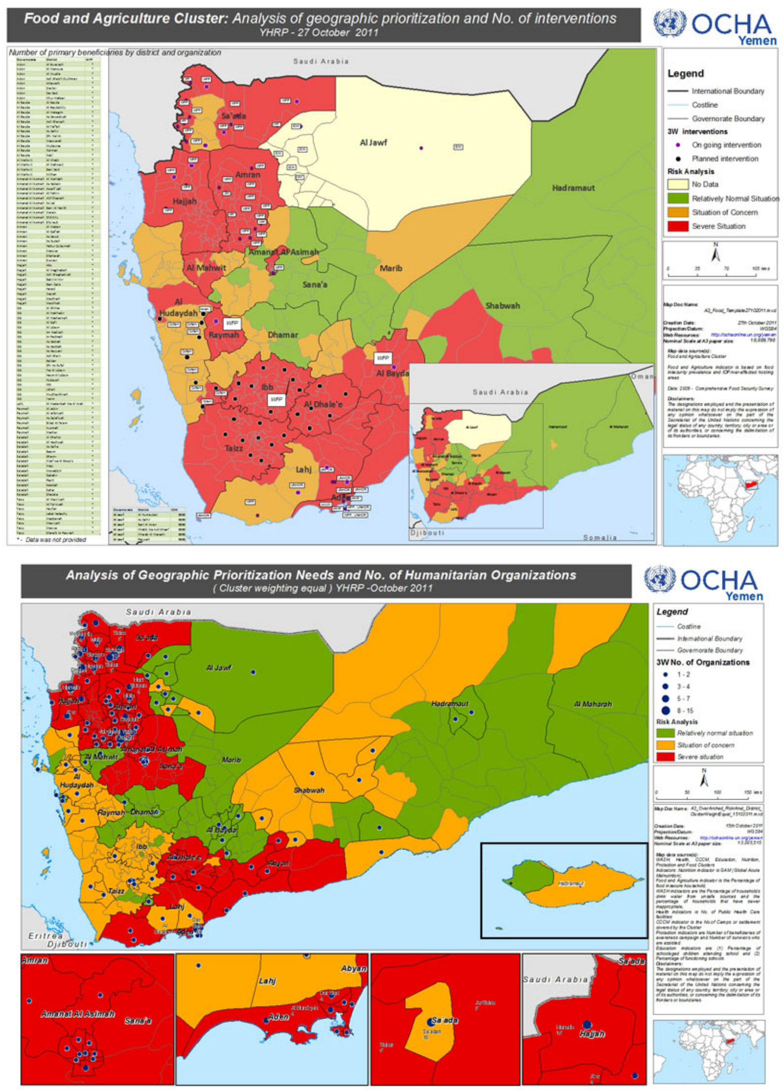


Figure 5.7 Gap Analysis for Single and Multiple Clusters

Question 13. Gap Analysis: The figures above show gaps in the distribution of humanitarian relief over time. Compared to existing methods of tracking the progress of humanitarian response, how useful is this type of analysis to you?

As was clear during the Phase 3 expert interviews, the calculation of gaps in relief is essential for effective coordination of humanitarian assistance. GIS is not needed to perform Gap Analysis, however it does provide a potential means to compare and communicate Who-What-Where (3W) data and Needs Assessment data, and to optimize the allocation of available resources. Whether GIS is used or not, the ultimate goal of Gap Analysis is to improve “situational awareness” to all organizations involved in responding to a humanitarian emergency.

The radial histograms used to portray the temporal dimension of Gap Analysis are basic Cartesian histograms, re-projected to compact information around a point of interest, such as a village or district.

These “analysis tool” do not constitute GIS-based analysis by themselves, but if combined with geospatial queries of underlying Needs Assessment and 3W data, they could convey relief trends that would otherwise remain hidden in disparate reports, tables or maps.

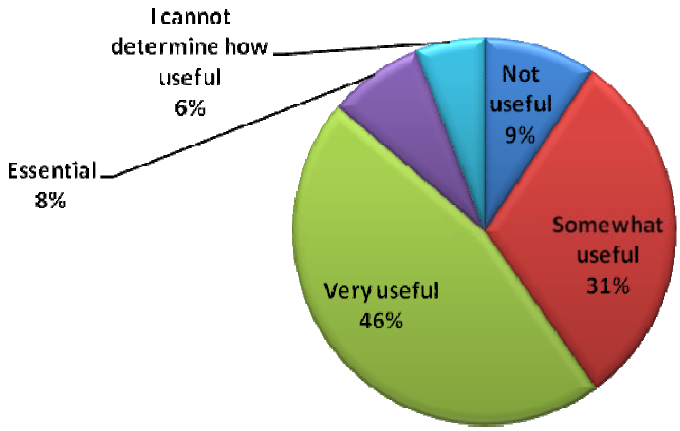


Figure 5.8 Utility of Gap Analysis

As illustrated in the chart above, 54% of the survey respondents felt that the above example of GIS-based Gap Analysis was very useful or essential to their decision making. Another 31% felt it could be somewhat useful, while the remaining 23% indicated that they felt the application was either not useful or indeterminate to them. Nearly two-thirds of them then replied to the follow-up question:

How would this type of analysis affect your decision-making?

Comments were provided by 101 of the 137 respondents; their collective remarks are summarized in the table5.6.

Table 5.6 Common Themes about Gap Analysis

Common Themes	**Repetitions**
Optimistic	
Gap analysis can help to avoid duplication and establish priorities for resource allocation.	25
These types of analyses and graphics are powerful ways to communicate a dynamic and complex situation to decision makers	16
These graphics reveal trends that otherwise remain hidden in spreadsheets or reports.	10
The examples illustrate the temporal as well as spatial dimension of responding to a humanitarian emergency.	9
This form of spatial analysis expedites the ability to respond to gaps.	7
Comparing the trends amongst sectors or clusters can reveal bottlenecks in the overall response, and explain their impact on the effort to provide effective aid/evaluate cluster performance.	8
Skeptical	
The lack of reliable data makes this type of analysis hard to perform and doesn't resolve the underlying problems with the perishability and inconsistency of field data.	12
These graphics are too complex for the average person to comprehend.	8
While helpful, this analysis doesn't replace the need for detailed statistics, tables and reports that explain the size of the gaps and the reason they have occurred.	7
Aggregation of data at this scale may be okay for strategic planning but it is not helpful for field-level decision making…data needs to be presented at a municipal/village level to truly impact relief distribution on the ground.	6
Tracking progress should not be limited to gaps in relief – it should ultimately answer whether victims are better or worse off compared to earlier stages of response.	4

While the opinions provide resounding support to the concept of performing Gap Analysis, they also point out that calculating gaps is not as much a GIS problem but a data management problem. There were opposing views with respect to understanding the radial histograms: one respondent said they were, “100 times better than a list of needs” while several others argued that they were, “too complex for decision makers.” The researcher regretted not showing Gap Analysis at a village or camp-scale, since many respondents argued that the above scenarios were shown at a scale too course to be useful at the field level.

Although the survey question didn’t provide an overwhelming endorsement of the use of Analysis tool, it did confirm that Gap Analysis is essential to effective coordination of humanitarian assistance. It was also emphasized that data availability is a stubborn challenge to performing Gap Analysis, something that GIS-based analysis cannot resolve without systematic reform of humanitarian information management practises.

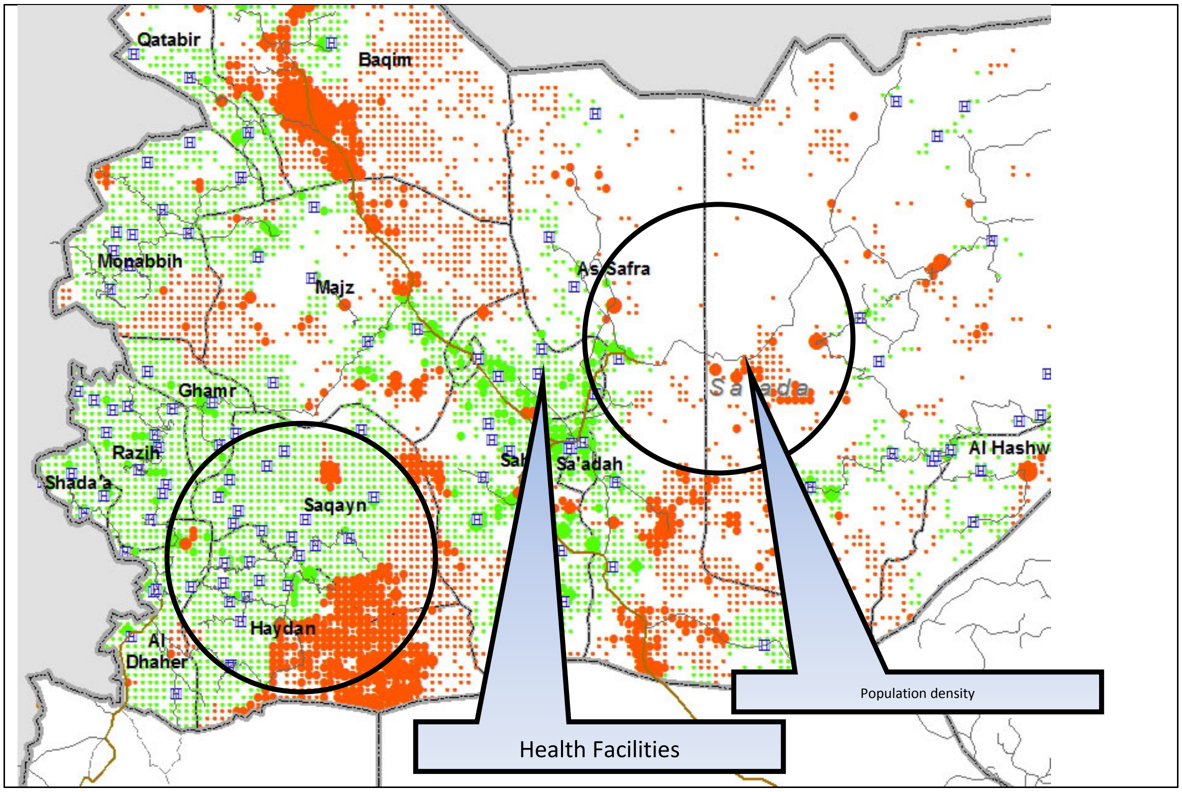


Figure 5.9 Range Analysis

Question 14. Range Analysis: The figure above shows how GIS can be used to calculate the number of settlements (or schools, hospitals, people, etc.) within a certain distance of a vaccination clinic (or road, food distribution point, etc.). How useful is this type of analysis to you?

A fairly simple GIS-based query, called "Range Analysis", can help to understand the proximity of various features in the field. In the context of humanitarian planning, it seems logical to assume that decision makers need to know how close or far their activities are to beneficiaries (or other features of interest). The survey respondents overwhelmingly agreed, with nearly three-quarters ranking the application as being either very useful or essential. Another 17% felt it might be somewhat useful to their operations, while only 4% saw no utility. Its relative simplicity, and its many possible applications, made Range Analysis one of the most popular types of GIS-based analysis in the survey.

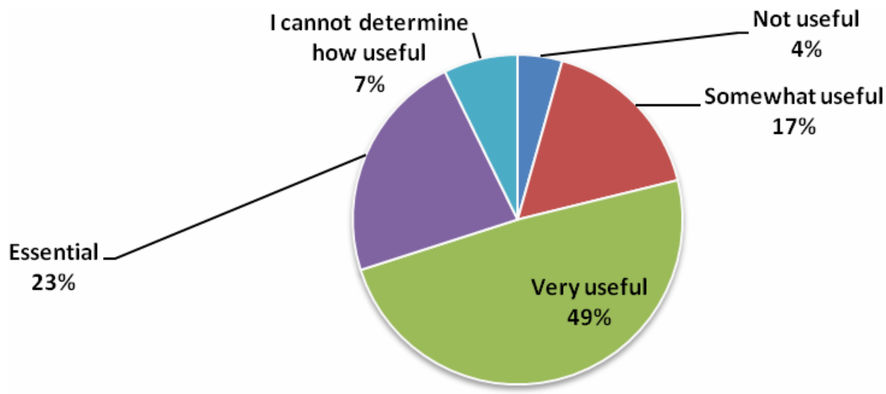


Figure 5.10 Utility of Range Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

One-hundred and ten survey respondents offered to elaborate on what they felt to be the ideal applications of, or concerns with, Range Analysis. the list of each response, summarized in the table below:

Table 5.7 Common Themes about Range Analysis

Common Themes	Repetitions

Optimistic	
To optimize location for new infrastructure and services.	24
To determine populations vulnerable to hazards or with insufficient access to humanitarian services	12
To strategically plan health, education, etc. delivery and maintenance.	17
To analyze cost and/or general effectiveness of humanitarian operations	6
To define "catchments" that optimize needs with available resources.	7
To select, design and manage camps based upon resource capacity constraints.	6
To anticipate post-disaster bottlenecks in relief distribution.	7
The simplicity of this analysis is appealing for communicating to non-technical decision makers.	5
To coordinate the humanitarian clusters/sectors.	3
To determine compliance with humanitarian standards such as SPHERE.	3
Skeptical	
While helpful it is not decisive by itself – more contextual information is necessary, especially terrain and actual transportation routes.	14
Unreliable population and 3W data limit the actual impact of Range Analysis in dynamic and poorly mapped regions.	6
It does not measure service impact or quality so it can be somewhat deceptive.	2
This is too simplistic, and provide little added value over currently available maps.	1

Survey participants from almost every thematic cluster wrote about the potential applications for Range Analysis to help them plan and monitor their activities. The simplicity of analysis and minimal data requirements seemed to be both appealing and worrisome to respondents, many of whom recognized the risk of ignoring impediments to straight-line travel. Especially encouraging was the frequent reference to "catchment" planning – the survey population seemed to be interested in exploiting Range Analysis to improve the location and conduct of humanitarian activities with respect to beneficiaries, surrounding hazards, and associated phenomena with an impact on their operations.

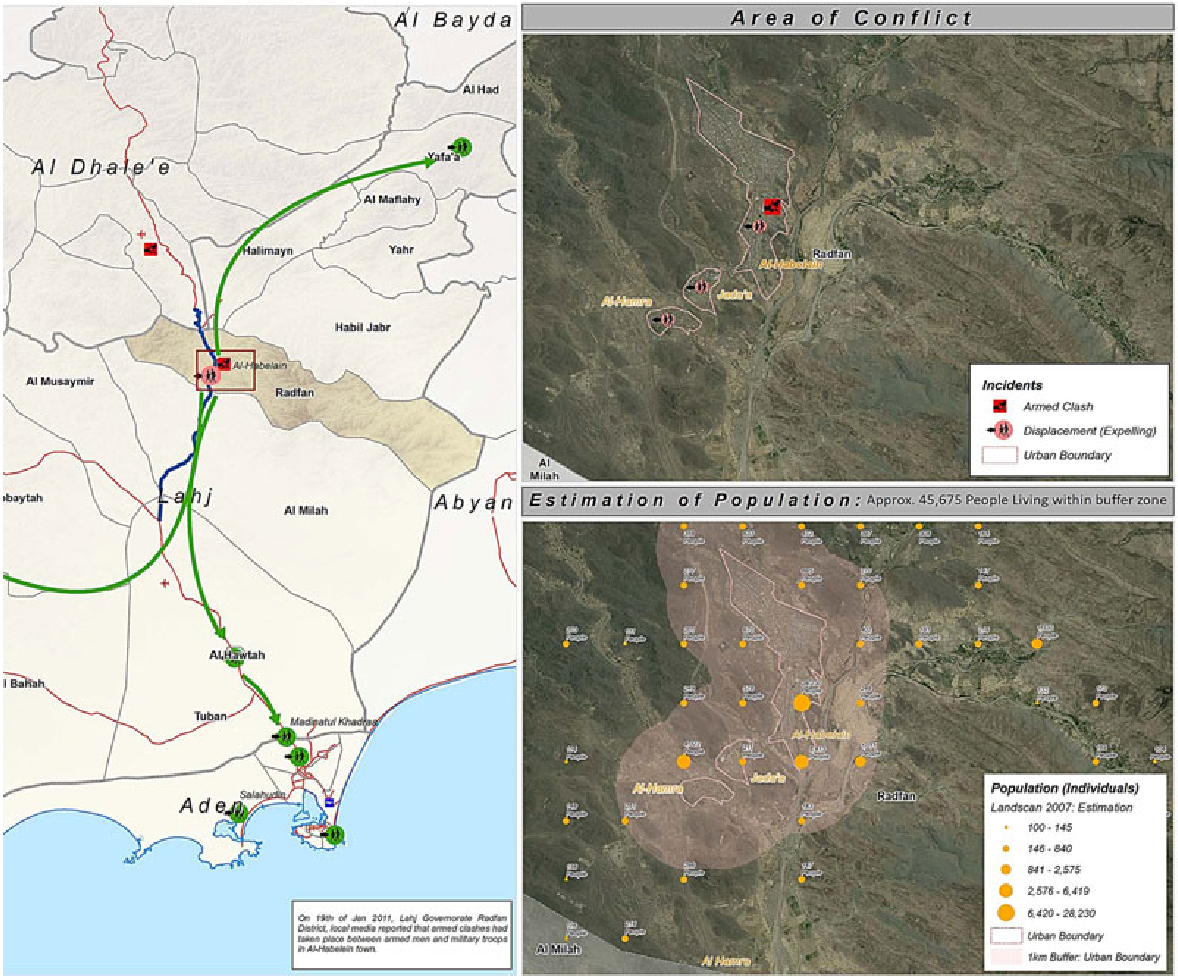


Figure 5.11 Zone Analysis

Question 15. Zone Analysis: The figure above shows how GIS can be used to calculate the total relief capacity (and compliance with humanitarian standards) within a certain area. How useful is this type of analysis to you?

Depending on the quality of a geodatabase, and the availability of specific analytical queries, Zone Analysis can be a powerful and automated tool to monitor service capacity and to assess compliance with assorted humanitarian standards. The survey respondents seemed to most interested in its utility at a village or camp-level, however the application could also be relevant at smaller scale, particularly when assessing relief provision to sparsely distributed populations. As illustrated in Figure 6.12, a total of 77% respondents thought that Zone Analysis would be very useful or essential to them. Another 18% indicated that it would be somewhat useful to their decision making; 9% of the respondents either felt it would not be useful, or opted not to rank the utility of this application of GIS-based analysis.

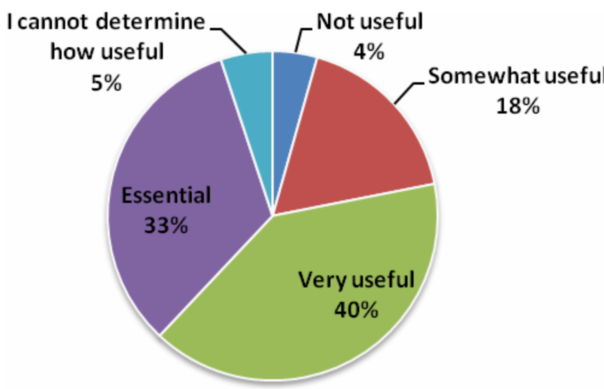


Figure 5.12 Utility of Zone Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

Ninety respondents commented on the application of Zone Analysis in the follow-up question. Common themes are summarized in the table below.

The application of Zone Analysis for monitoring of humanitarian standards generated several interesting remarks. Some respondents appeared keen, indicating that it would be, “excellent for ensuring compliance with standards – especially if funding is reliant on meeting targets”. Others cautioned that, “SPHERE guidelines are only indicators and should not be considered out of context”. This concern seemed to stem, at least in part, from the fact that most camp operations are too dynamic to have reliable population density data – a key ingredient for determining standards compliance. The majority of opinion was clearly favorable towards using Zone Analysis to optimize humanitarian services at the camp-level, within applicable resource constraints and aid provision targets.

Table 5.8 Common Themes about Zone Analysis

Common Themes	**Repetitions**
Optimistic	
To select, design and manage IDP/refugee camps based upon resource capacity constraints.	16
To better plan and/or monitor water, sanitation, education, health, etc. projects.	12
To identify or explain gaps in relief, particularly at a village/camp level.	10
To determine compliance with humanitarian standards such as SPHERE.	10
To map vulnerability to hazards such as UXO/landmines or ethnic violence.	6
To coordinate the humanitarian clusters/sectors.	6
To rapidly communicate key information and visualize limitations/challenges.	6
To plan supply routes and locations for logistics infrastructure	5
To analyze cost and/or general effectiveness of humanitarian operations.	5
To understand how demographics may impact relief distribution	3
Skeptical	
While helpful it is not decisive by itself – more contextual information is necessary.	6
Unreliable population and 3W data limit the actual impact of Zone Analysis in dynamic and poorly mapped regions.	5
It does not measure service impact or quality so it can be somewhat deceptive.	3
This has little impact on decision making, and is just a “pretty picture”.	2

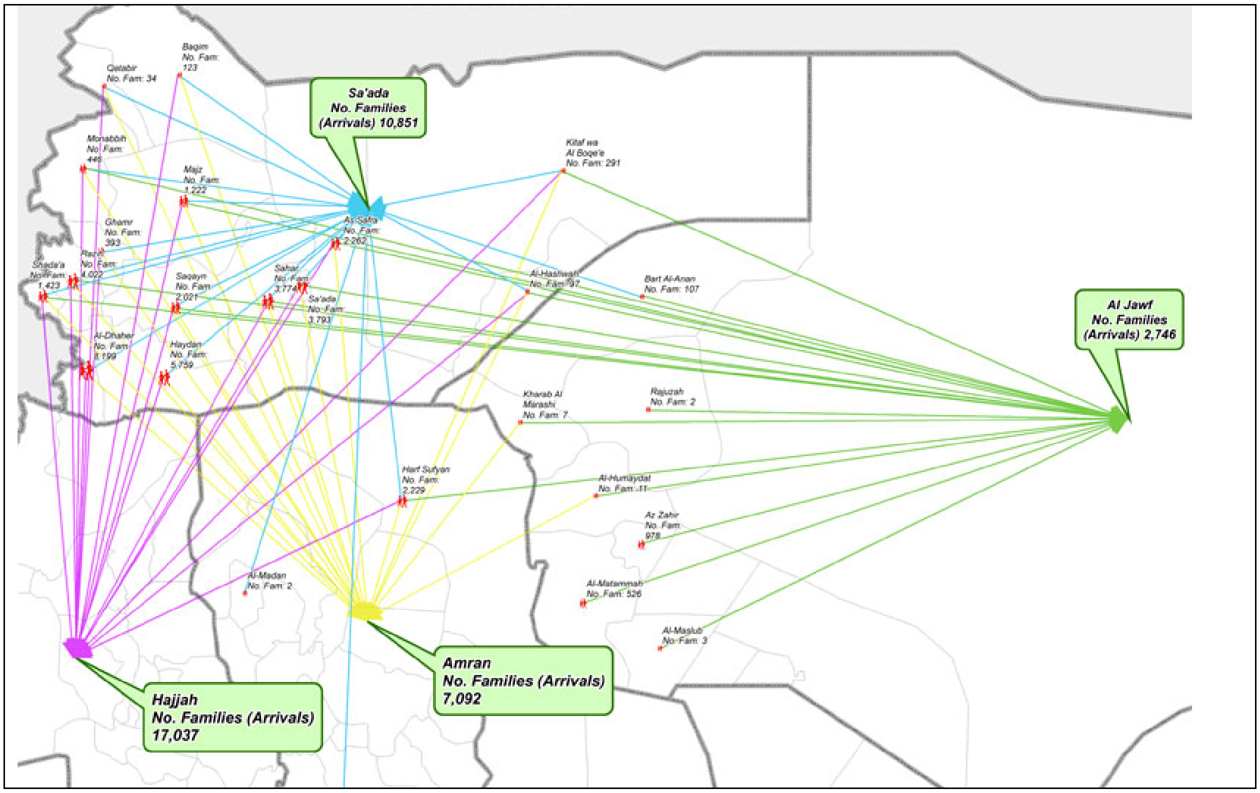


Figure 5.13 Measurement Analysis

Question 16. Measurement: The figure above shows how GIS can be used to measure the straight-line or driving distance between two locations. It also shows how it can be used to calculate the areal extent of certain features – this can be useful to approximate volumes of pesticide for anti-malarial spraying, or estimating resource potential of farmland or forests. Compared to existing methods of distance and areal measurement, how useful is this type of analysis to you ?

The precise measurement of distance or area is one of the simplest and most obvious applications of GIS-based analysis, and the survey requested participants to rate its usefulness within the context of responding to humanitarian emergencies. Just over 57% of the respondents stated that Measurement would be very useful or essential to them, with another 28%

indicated that it would be somewhat useful in their decision-making. Interestingly, 15% of the respondents were not able to determine the utility of Measurement or did not feel it would be useful. Perhaps the general imprecision of decision making during emergencies undermines the impact of very precise measurements that can be provided by GIS. It is understandable why decision makers are used to working with relative, and not absolute measures; old maps, outdated field reports, constantly moving populations and ever-changing infrastructure are the norm during humanitarian emergencies.

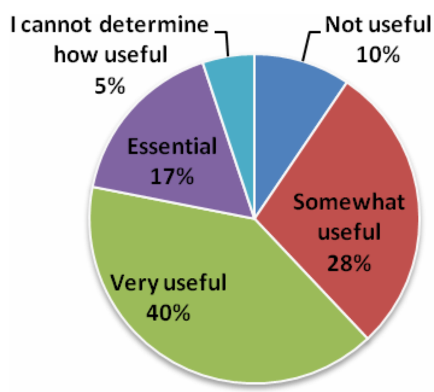


Figure 5.14 Utility of Measurement Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

As summarized in the table below, there were many interesting suggestions for the application of Measurement.

Table 5.9 Common Themes about Measurement Analysis

Common Themes	Repetitions
Optimistic	
To plan logistics (inventory levels, resource allocations, etc.).	15
To estimate transportation budgets and improve operational efficiency.	9
To estimate transportation times.	7
To plan staff deployments and IDP/refugee movements	6
To identify the best locations for humanitarian services.	5
To optimize transport modes.	5
To mitigate hazards (vector control, etc.)	5
To evacuate at-risk populations.	5
To optimize transport routes.	4
To communicate and promote better understanding in the field and HQ	3
Skeptical	
The example was unclear or lacked sufficient detail to be compelling.	7
Using GIS for measurement is unnecessary if you access local knowledge regarding the best routes, approximate driving times, etc.	6
Use GIS for measurement is unnecessary if you use available maps.	2

The above themes, whilst encouraging, illustrate the methodological challenge of conducting the survey without biasing the results through leading questions, oversimplification, etc. (e.g. the researcher is unconvinced that transportation cost estimation or vector control would have featured so prominently in the feedback had they not be used in the survey example). Regardless, the application of Measurement did resonate with a significant portion of the survey participants, especially with regards to logistics planning.

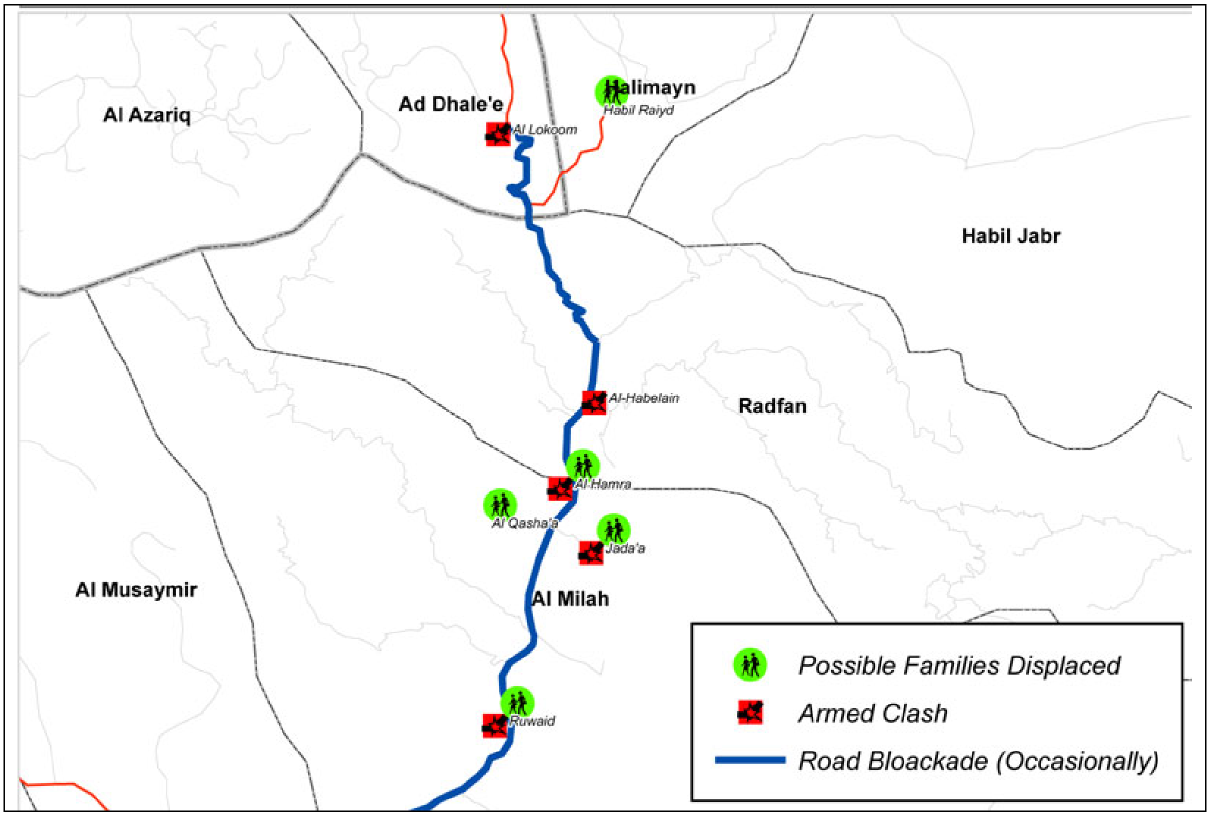


Figure 5.15 Vulnerability Estimation

Question 17. Vulnerability Estimation: The figure above shows how GIS can be used to estimate the areas worst affected by an earthquake. Populations that are most vulnerable to receiving inadequate relief are anticipated, based upon their distance to main routes, local capitals, territorial boundaries, and ongoing relief capacity. Compared to existing methods of vulnerability estimation, how useful is this type of analysis to you?

Question 17 illustrated a fairly rudimentary type of GIS-based transformation called buffer analysis, in an example produced by the UN OCHA in Sana'a after the June, 2011armored conflict in the southern part of Yemen. By buffering transportation routes, district boundaries, and local capitals, the UN OCHA attempted to identify which villages were close to the conflict areas, but far from lines of communication and likely relief distribution points. Villages that met some or all of the criteria where then identified as being most vulnerable to insufficient humanitarian assistance.

Nearly three-quarters of the survey respondents found Vulnerability Estimation to be either essential or very useful their operations. 10% respondents saw at least some utility. Only 8% respondents thinkthat it was not useful, with remainder opting to reserve judgment.

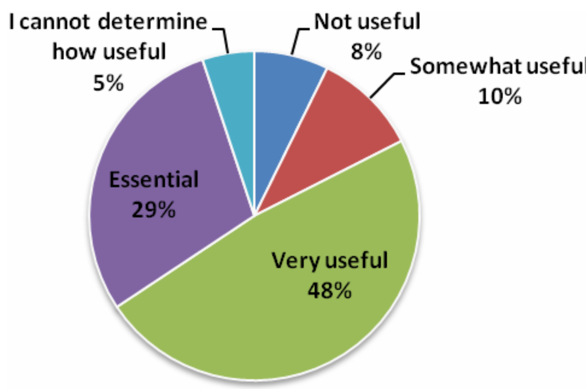


Figure 5.16 Utility of Vulnerability Estimation

What would be your ideal application(s) for this type of GIS-based analysis?

Common themes regarding the GIS-based Vulnerability Estimation are summarized in the table below:

Table 5.10 Common Themes about Vulnerability Estimation

Common Themes	Repetitions
Optimistic	
To estimate vulnerable populations (at risk after natural disasters but also conflicts and socio-ethnic violence), before or after an emergency.	12
To coordinate clusters and plan response strategies according to Gaps.	11
To prioritize distribution of humanitarian assistance.	11
To support response not only after earthquakes but almost any emergency, including flooding, forest fires, missing persons, violence, epidemics, etc.	8
To plan transportation and logistics of people and supplies.	7
To prepare and mitigate isolated communities with adequate self-help capacity, evacuation strategies and building codes.	6
To provide richer context in stakeholder briefings.	5
To quickly produce a vulnerability estimate before experts can get into the field.	4
To make response planning more empirical and less subjective.	4
To assess Needs before and after field truth data starts to become available.	3
Skeptical	
This type of analysis is only useful it if linked to accurate gazetteer (population/settlement) statistics and 3W data, imagery and ground trothing.	8
This application of GIS is unreliable and potentially misleading because it employs arbitrary buffer distances and excludes of actual route conditions (e.g. bridge safety, trail washouts, road blockages, etc.), social networks, and politics	7
Unless data is ready before the disaster, this will take too long to be effective.	3

The survey respondents indicated a remarkable enthusiasm for this application of GIS, on the condition that the analysis was tightly linked to accurate gazetteer information as well as up-to-date 3W data. The need to know where victims of an emergency are likely to be, and to set priorities in the absence of complete field reports, could make this a perennial form of GIS-based analysis - however collecting core data layers before an emergency, and incorporating field reports into the analysis, are fundamental to making Vulnerability Estimation “actionable”.

Question 18. Site Selection: GIS can be used to identify the best locations for campsites (or schools, hospitals, helipads, etc.), based upon certain criteria such as water availability, land cover, accessibility, hazards, etc. In other words, by layering existing knowledge of land cover, terrain, hydrology and relief activities, it is possible to apply GIS-based analysis to optimize the locations for relief operations. How useful is this type of analysis to you?

This question, to which participants responded without any visual aid, was the most popular of all of the survey examples. 80% of the respondents felt the use of GIS-based analysis for site selection was either essential or very useful to them when making decisions during humanitarian interventions. 22 respondents were unsure or unconvinced of the utility of the application, as illustrated in the figure below.

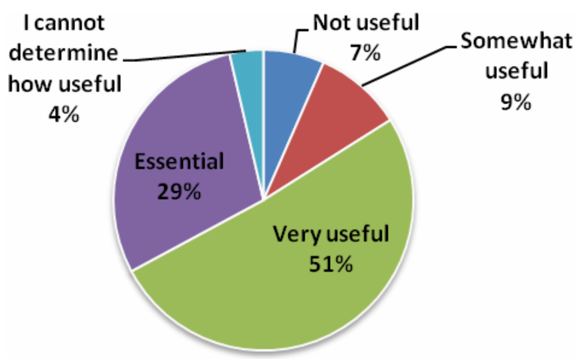


Figure 5.17 Utility of Site Selection

What would be your ideal application(s) for this type of GIS-based analysis?

The respondents explained as well as qualified their enthusiasm about GIS-based Site Selection in the follow-up question. Common themes are summarized in the table below:

Table 5.11 Common Themes about Site Selection

Common Themes	Repetitions
Optimistic	
To select optimal locations for various humanitarian services (as described in the survey question itself).	51
To monitor and evaluate program efficiency.	7
To plan evacuation strategies and safe havens.	5
To coordinate the clusters.	4
To identify areas in which hazards overlap with population settlements, in order to reduce the vulnerability of those most at-risk.	4
Site selection must also take into account meteorology (to map snow coverage, *wadi* flood plains, etc..) and hydrology (to ensure sufficient water and sanitation capacity).	4
To minimize the environmental impact of humanitarian operations.	2
Skeptical	
This application is only possible if the require data exists, is exploited in a timely manner, and is truthed with field data as it becomes available.	8
This is fine theoretically, but politics, land rights and the ever-changing locations of displaced people will ultimately determine where organizations will be allowed to establish their operations.	8
Site selection seems to be an ideal application, but it has been “oversold” and “undelivered”.	2
This needs to incorporate Gap Analysis (Assessed Needs – 3W) in order to be effective	2

There was little disagreement amongst the respondents. Many remarked that the utility of GIS-based Site Selection was contingent on reliable data, and frequent validation with realities on the ground. Several also suggested that this type of analysis must be provided very quickly in order to be useful, since humanitarian organizations select and commit to their bases of operation soon after deploying to the disaster scene.

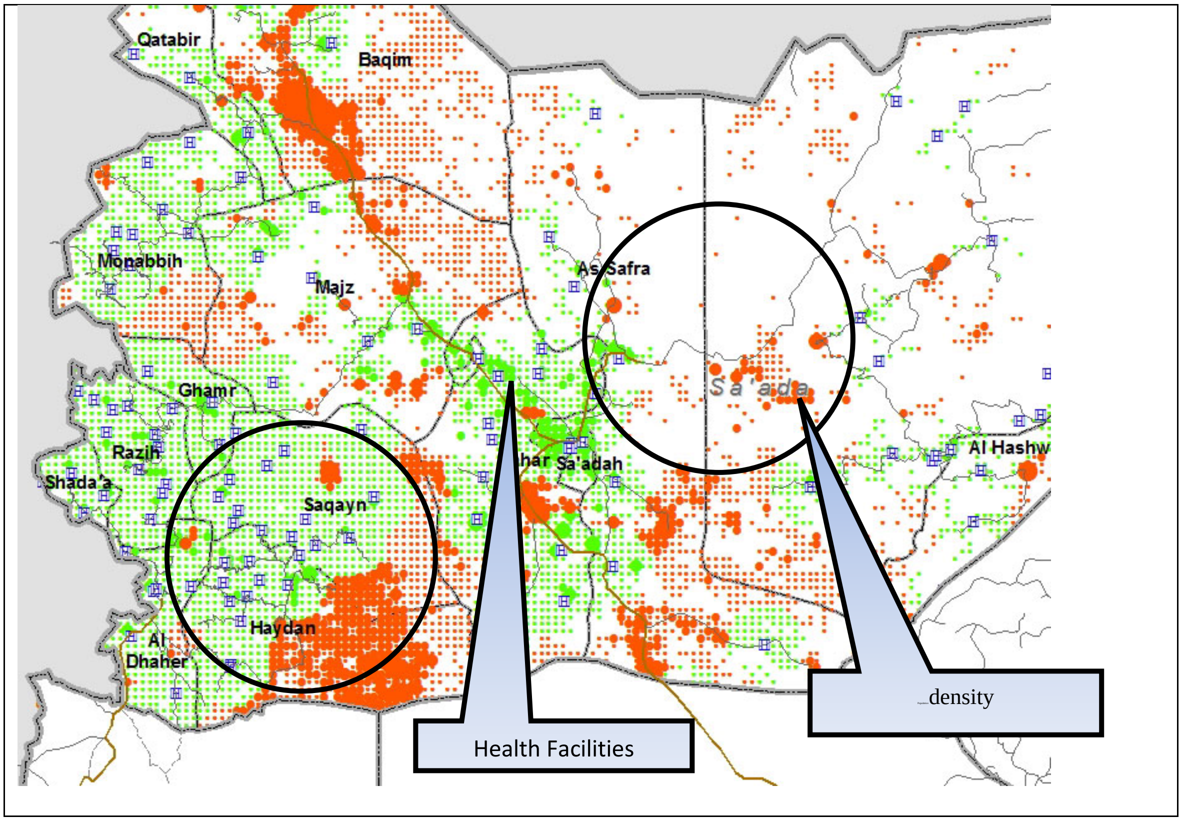


Figure 5.18 Service Optimization

Question 19. Service Optimization: The figure above shows how GIS can be used to determine the best locations to service a dispersed population, based upon certain travel goals. Compared to existing methods of service optimization, how useful is this type of analysis to you?

The selection of service points based upon travel times and transportation modes is a form of GIS-based analysis called Point Optimization. About two-thirds of respondents rated this application as being very useful or essential to them, with another 14% stating that it would be somewhat useful. Approximately 6% stated that they were unsure or unconvinced of the utility of GIS-based Service Optimization. It is worth restating that since this was not a survey about feasibility, no attempt was made to rank this (or any other application) differently because it involved greater sophistication. Point optimization requires a GIS transportation network populated with segmented route information describing factors which affect navigability and speed of travel: speed limits, type of roads, # of lanes, traffic patterns, restrictions for travel, etc. all need to be reflected by the transportation network in order to perform point optimization effectively. The survey respondents were not required or expected to take this into account.

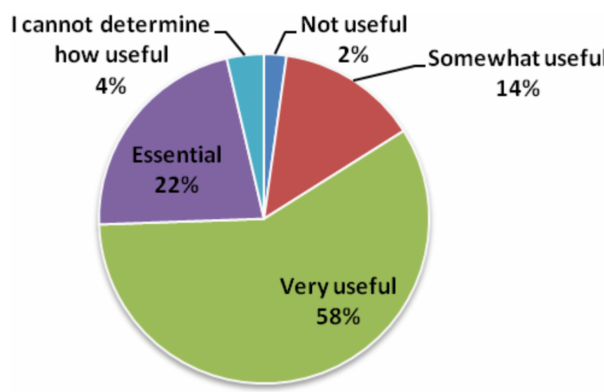


Figure 5.19 Utility of Service Optimization

What would be your ideal application(s) for this type of GIS-based analysis?

The standard follow-up question generated 88 comments, summarized in the table below:

Table 5.12 Common Themes about Service Optimization

Common Themes	**Repetitions**
Optimistic	
To minimize commuting times from settlements to schools, clinics, distribution points, and other services.	24
To plan and coordinate humanitarian operations.	13
To detect and resolve gaps in service provision.	9
To monitor and evaluate program efficiency.	4
Skeptical	
This is fine theoretically, but politics, land rights and the ever-changing locations of displaced people will ultimately determine where educational, health, etc. centers can be established.	9
This is better suited for longer-term developmental planning rather than short-term provision of humanitarian assistance.	7
This application depends on reliable and rapid access to data that is hardly ever available in emergency situations.	4
This type of analysis also needs to consider security conditions in order to be meaningful.	2
This type of analysis can be done using less sophisticated, traditional methods	2
Transportation times, while important, are not the greatest concern.	1

The above themes confirmed a strong interest in this type of GIS-based analysis, particularly for longer-term development planning. Several participants cautioned not to underestimate the importance of local politics on where humanitarian services are established, while other expressed doubt that sufficient data, or justification, existed to support GIS-based Service Optimization in most humanitarian emergencies.

Question 20. Route Optimization: You may be familiar with Internet-based route planning services, which allow the user to input an origin and destination and then obtain a turn-by-turn set of directions. When transportation networks are complex (or constantly changing), GIS-based analysis can quickly identify the shortest or fastest route between two or more locations. Compared to existing *methods of navigation and route planning during humanitarian operations, how useful is this type of analysis to you?*

This question, to which participants were also required to respond without any visual aid, attempted to measure if GIS-based navigation services could be decisive during humanitarian emergencies. As explained in the preceding review of the Question 19, the complexity of GIS-based optimizations was not considered in determining their utility, but it would be a major factor if future research was to determine feasibility of Route Optimization. 11% of respondents felt this application would be essential to them compared to alternative forms of navigation and route planning. Nearly the same number stated they were either unsure or unconvinced of its utility.

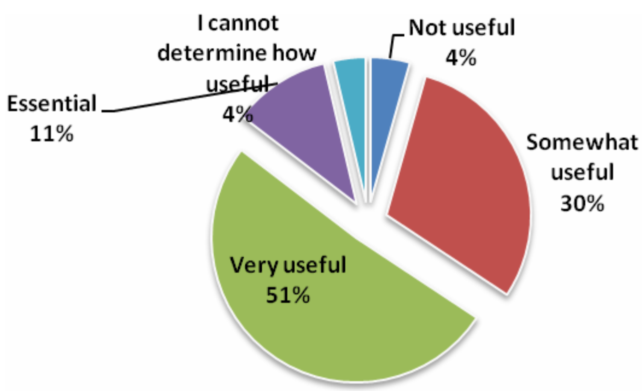


Figure 5.20 Utility of Route Optimization

Just over two-thirds of respondents felt Route Optimization could be somewhat to very useful to their planning decisions.

What would be your ideal application(s) for this type of GIS-based analysis?

Almost half of the 137 survey respondents elaborated upon their opinion; the most common remarks are summarized in the table below:

Table 5.13 Common Themes about Route Optimization

Common Themes	**Repetitions**
Optimistic	
To navigate changing road conditions due to landslides, changing weather or security conditions, and other hazards.	13
As long as it incorporates reliable and timely information, GIS-based Route Optimization could be an essential component of the standard suite of humanitarian coordination services that are provided.	10
To plan emergency access and evacuation routes.	9
To maximize the impact of available resources during dynamic conditions	8
This type of analysis also needs to consider security conditions in order to be meaningful.	7
To save time and/or expense in distributing humanitarian assistance.	6
Skeptical	
Route optimization only works if changing conditions are reporting in real-time…even a few inaccuracies will be fatal to the reliability of such a system.	12
GIS would be overkill – local drivers and other low-tech knowledge is cheaper and more reliable.	12
Roads are not complicated enough to justify such a complex investment.	5
This application depends on reliable and rapid access to transportation data that is hardly ever available in emergency situations.	5
This is better suited for longer-term developmental planning rather than post-disaster relief coordination.	4

Like the previous survey question, there was little disagreement amongst the respondents. They recognized the potential utility of the application, but also cautioned that the data necessary for GIS-based Route Optimization rendered it impractical or even unjustifiable in most countries. A significant number of respondents also doubted whether such analysis could be decisively superior to the expertise of local drivers.

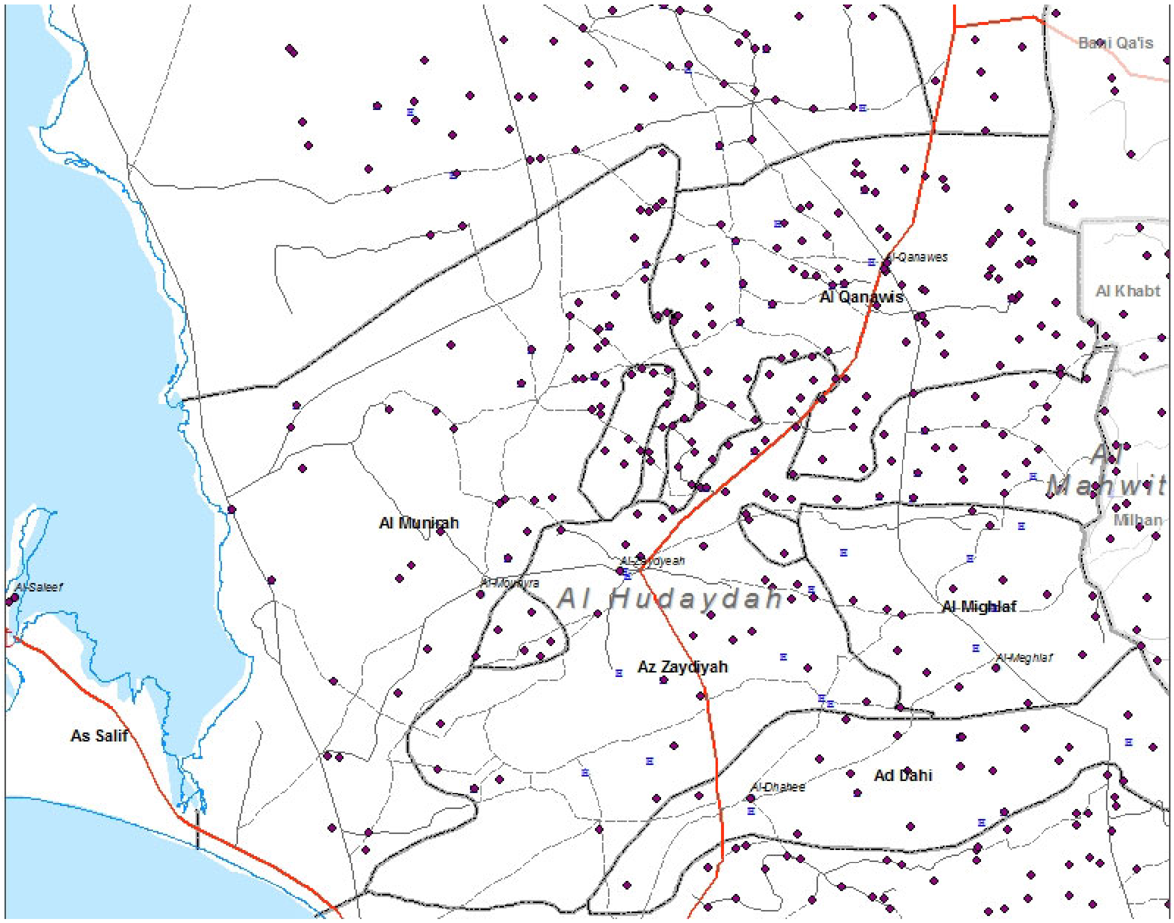


Figure 5.21 Central Feature Analysis

Question 21. Central Feature Analysis: The figure above shows how GIS can be used to calculate the most central point amongst a set of unweighted points (which might represent villages, vacant office buildings, etc.). Compared to other methods of finding the best location to establish relief operations, how useful is this type of analysis to you?

GIS-based statistical analysis has the potential to identify locations, trends and relationships across one or more thematic layers. This survey question tested the usefulness of determining the Geostatistical equivalent to the "median" amongst a set of points. Only 29 % of respondents felt it would be essential or very useful to them, which was the lowest level of utility amongst the applications surveyed. Almost 20% of respondents stated that they were unsure or unconvinced of its usefulness: a confirmation that this was the least compelling of the 13 examples of GIS-based analysis included in the survey.

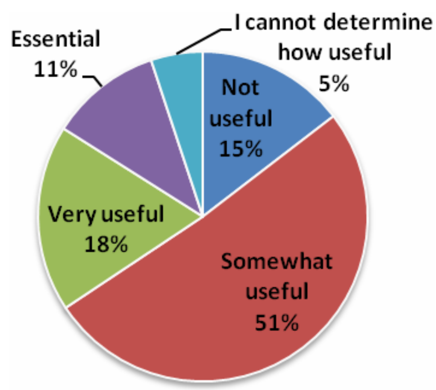


Figure 5.22 Utility of Central Feature Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

Table 5.14 summarizes the views of the survey respondents:

Table 5.14 Common Themes about Central Feature Analysis

Common Themes	Repetitions
Optimistic	
To develop a preliminary operating plan before arriving in the field.	8
To optimize selection of operating bases.	6
To minimize aggregate travel times for widely distributed populations that are dependent upon one central location for humanitarian relief services.	4
To eliminate accusations of favoritism when deciding where to establish high-profile humanitarian activities.	2
Skeptical	
This application is oversimplified and is not helpful without incorporating other factors such as: transportation infrastructure, water sources, security conditions, rental rates, the location of other agencies, terrain, etc.	20
Local knowledge and realities will typically overrule the utility of such analysis.	7
Centrality is not always the most important factor when selecting a base of operations.	5
This application depends on reliable and rapid access to data that is hardly ever available in emergency situations – even P-Codes are unreliable and too dynamic to be use for such precise analysis.	5
This is only possible if field conditions are not changing rapidly.	2
Central Feature Analysis if of limited utility for most organizations.	2
Such information will concentrate relief agencies in one location and distort prices – it is better for agencies not be completely centralized.	2

This application clearly appeared to oversimplify the process for selecting operating bases, and survey respondents appeared doubtful that such analysis could be useful for anything more than a general reference before deploying to the field. Once in the field, however, there were many other factors that took precedence for deciding which location at which to establish relief operations.

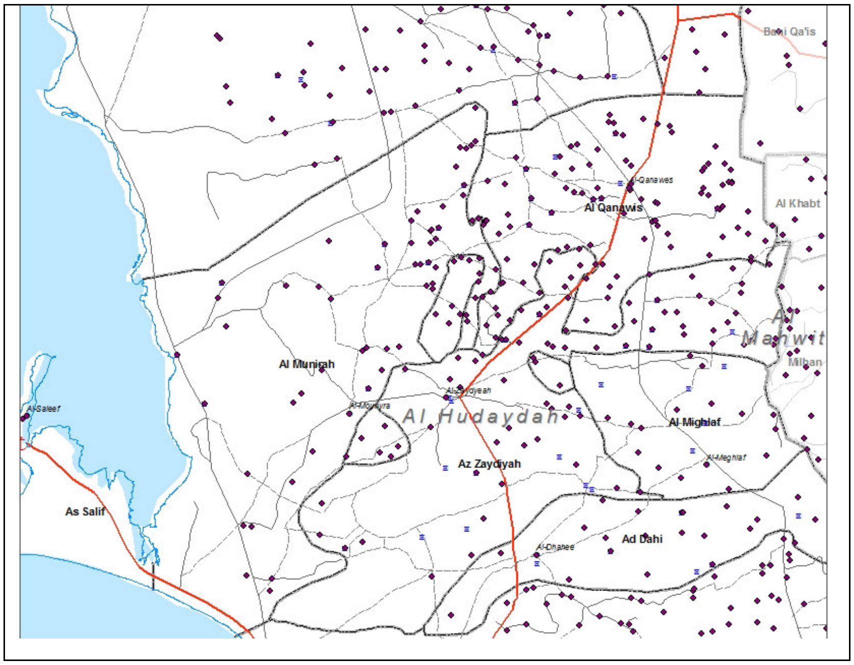


Figure 5.23 Exact Center Analysis (Weighted)

Question 22. Exact Center Analysis: The figure above shows how GIS can be used to calculate the exact center amongst a set of points (weighted to reflect village populations, agricultural output, AIDS/HIV infection rates, etc.). Compared to existing methods, how useful is this type of analysis to you?

The survey tested another form of GIS-based statistical analysis, which computes the Geostatistical equivalent of the “weighted mean” amongst a set of points. The survey respondents found this application slightly more useful than Central Feature Analysis, with just over 42% stating that it would be very useful or essential to their decision making. The same number felt it would be somewhat useful to them, with the remainder indicating that they were either unsure or unconvinced it would be useful at all during humanitarian emergencies.

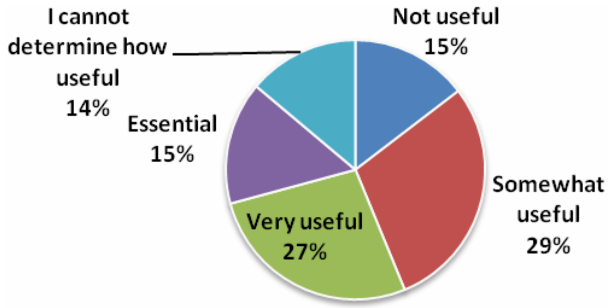


Figure 5.24 Utility of Exact Center Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

Not surprisingly, the feedback was very similar to that provided in Question 21:

Table 5.15 Common Themes about Exact Center Analysis

Common Themes	Repetitions
Optimistic	
Weighted points are essential to deciding upon centrality.	8
To develop a preliminary operating plan before arriving in the field.	8
To optimize selection of operating bases.	7
To minimize aggregate travel times for widely distributed populations that are dependent upon one central location for humanitarian relief services.	5
To eliminate accusations of favoritism when deciding where to establish high-profile humanitarian activities.	1
Skeptical	
This application is oversimplified and is not helpful without incorporating other factors such as: transportation infrastructure, water sources, security conditions, rental rates, the location of other agencies, terrain, etc.	6
Local knowledge and realities will typically overrule any utility of such analysis.	5
Centrality is not always the most important factor when selecting a base of operations.	3
This application depends on reliable and rapid access to data that is hardly ever available in emergency situations – even P-Codes are unreliable and too dynamic to be use for such precise analysis.	3
Exact Center Analysis if of limited utility for most organizations.	2
This is better suited only when settlements and field conditions are not changing rapidly.	1

The survey participants who responded to the follow-up question appreciably preferred the use of weighted versus unweighted points – an indication that relative levels of demand must be considered when calculating centrality. In general, however, the survey sample was not convinced of the utility for Exact Center Analysis en masse, and at best it would be decisive in only a few situations.

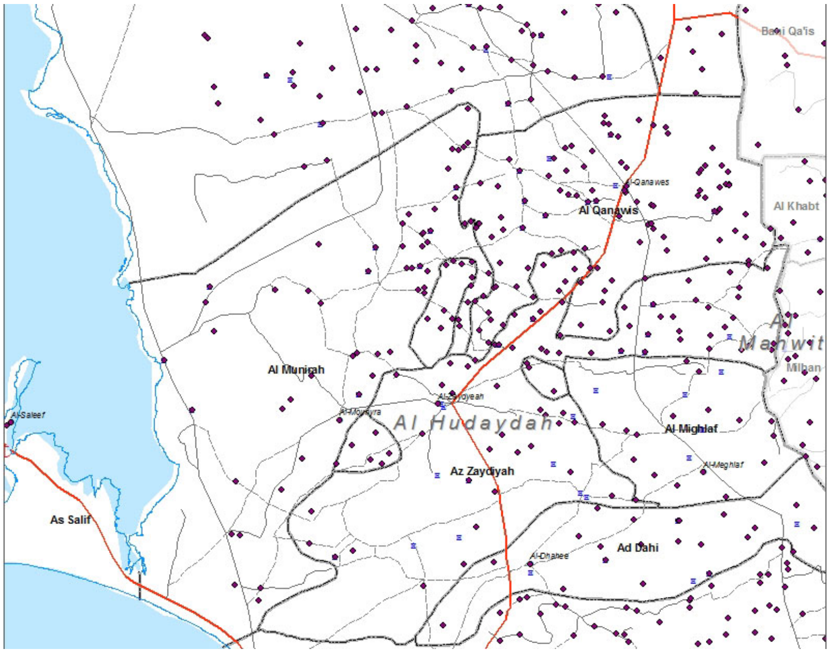


Figure 5.25 Cluster Analysis

Question 23. Cluster Analysis: The figure above shows how GIS can be used to identify if a series of features is correlated (i.e. clustered) with other phenomena. The purpose of cluster analysis is to determine if the distribution of a set of features is related or random, and to investigate causeand-effect relationships. The most common applications of cluster analysis have been in epidemiology (detecting possible sources of disease outbreaks) and crime analysis (anticipating the location and tactics of criminals). How useful is this type of analysis to you?

A third application of GIS-based statistics tested in the survey was Cluster Analysis. The response from the survey participants was dramatically different from the previous two questions, with more than two-thirds indicating that it would be very useful or essential to their decision-making during humanitarian emergencies. Eight percent of the 137 respondents did not understand or preferred not to rate the application, while the remaining 12% respondents felt it would be of only little or no use in their context.

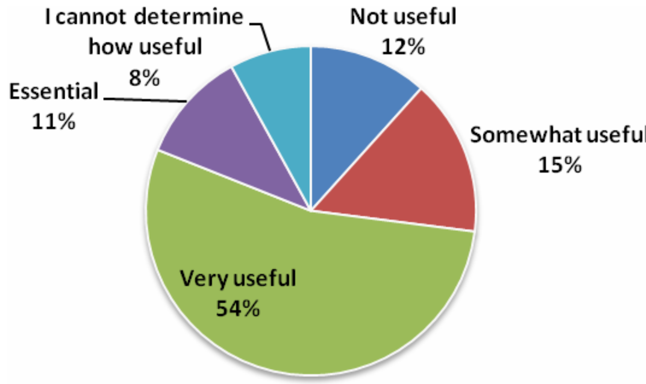


Figure 5.26 Utility of Cluster Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

As indicated in the table below, the Cluster Analysis application clearly resonated with the survey participants:

Table 5.16 Common Themes about Cluster Analysis

Common Themes	Repetitions
Optimistic	
To predict or investigate criminal or epidemiological phenomena.	21
To plan deployment of security patrols and peacekeeping forces.	13
To detect event patterns and discover cause-and-effect relationships.	11

As long as the data and capabilities are available, Cluster Analysis could be very helpful for assessing needs, planning surveys, and reporting more effectively.	10
To monitor trends and plan relief distribution strategies.	9
To map UXO contamination and other hazardous areas	3
Skeptical	
Cluster analysis requires reliable demographic, income, health, etc. data, which is almost never available during humanitarian emergencies.	4
This is more suitable for longer term response and developmental planning than for relief operations.	1

The Cluster Analysis application sparked significantly more interest than Central Feature or Exact Center Analysis. Surprisingly, fewer respondents were concerned about the availability of sufficient data or capability than for the other applications of GIS-based statistics; Cluster Analysis is, ironically, the most advanced of the three applications. One respondent wrote, “this kind of thing is data intensive but offers a lot of promise.” That optimism was shared by many survey participants, who suggested that Cluster Analysis could be used to map voting patterns, better target aid programs, brief stakeholders, reduce operational risks, and plan inventories of humanitarian supplies.

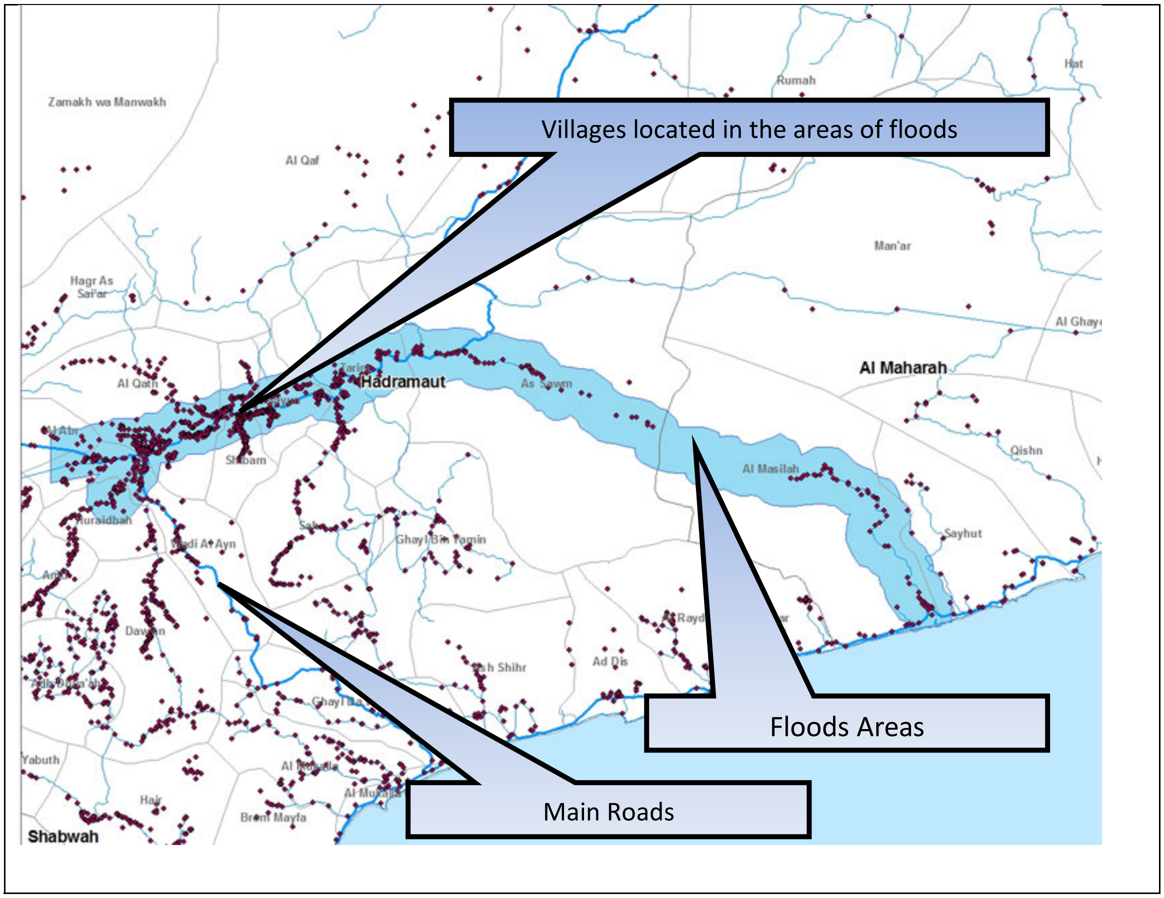


Figure 5.27 "What if?" Analysis

Question 24. "What if" Analysis: GIS can be used to simulate how changes in one or morevariables might impact a humanitarian relief operation. For example, the figure aboveillustrates the extent of floods in Hadramout Governorate (Yemen) ; by simulating different levels of floods, it could be possible to predict changes in road accessibility and relief needs at different elevations. Another example of this type of GIS-based analysis is the prediction of human migration patterns based upon relief locations, weather patterns or security trends. Of course, such types of analysis are complex and inherently prone to error. How useful is this type of analysis to you?

One of the most powerful applications of GIS-based analysis is hypothesis testing and simulation analysis, more easily understood as "What if" Analysis. The number of possibilities to conduct "What if" Analysis is infinite, making it extremely difficult to assess its utility in a representative sense. Based upon the one example offered in the survey, nearly two-thirds of the participants rated "What if" Analysis as either very useful or essential to their decision making. Nearly a quarter thought it would be at least somewhat useful. Only 9 out of 137 respondents indicated that they thought this category of GIS-based analysis would not be useful to coordinating humanitarian assistance.

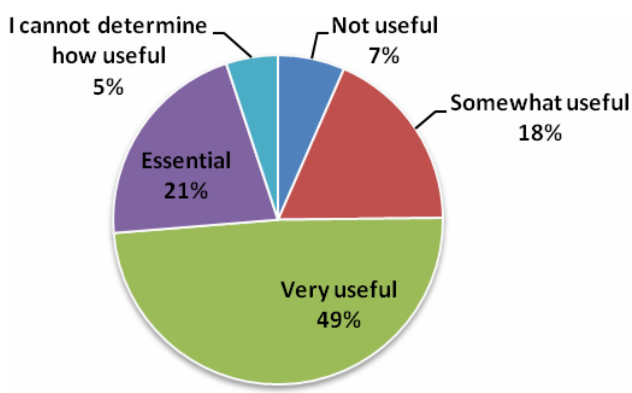


Figure 5.28 Utility of "What if?" Analysis

What would be your ideal application(s) for this type of GIS-based analysis?

The application of GIS-based hypothesis testing generated a variety of feedback from the survey respondents. Seventy-five individuals offered comments, which are summarized in the table below:

Table 5.17 Common Themes about "What if?" Analysis

Common Themes	**Repetitions**
Optimistic	
To optimize relief according to changing environmental, weather or security conditions.	12
To develop contingency plans, and prepare for future emergencies.	11
This is probably the most compelling application of GIS-based analysis.	9
To model hazard scenarios and mitigate risk.	9
To pre-position resources based upon likely or worst-case scenarios.	8
To coordinate and improve overall humanitarian assistance.	8
As long as its weaknesses are clearly understood, this application could be informative during decision making.	5
To design rapid access and evacuation strategies.	4
Skeptical	
There are too many variables to make this a decisive or reliable tool; since hypothesis testing is, "complex and prone to error" how can it be useful?	7
This is more suitable for longer term response and developmental planning than for relief operations.	5
Who has the time to do this during an emergency?	3

The survey respondents seemed to be split in opinion: a majority felt that this could be one of the most powerful applications for GIS while a minority argued that there was neither the time nor sophistication to conduct "What if" Analysis during humanitarian emergencies. Those who advocated for its use repetitively mentioned contingency planning as an application ideally suited for this form of GIS-based analysis, an indication that they believed that there certain *was* enough time to conduct meaningful analysis before an emergency, if not afterwards.

The final category of GIS-based analysis was Geovisualization. Prior to testing its utility, the survey respondents were asked:

Question 25. Are you familiar or do you use web-based Geovisualization tools such as Google Earth, Microsoft Virtual Earth or ArcGIS Explorer?

This question was necessary in order to be able to ask Question 26, since the survey was not able to adequately demonstrate the interactive experience of Geovisualization. Had a significant number of survey participants indicated that they were not familiar with web-based tools such as Google Earth, the results for Question 26 would not have been reliable. Fortunately, the vast majority of those surveyed indicated that they used, or were at least familiar with, Geovisualization tools.

The figure below shows that at least 132 of the 156 respondents, or nearly 85%, were ready to assess the utility of Geovisualization.

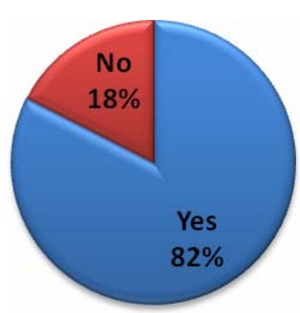


Figure 5.29 Survey Participants - Familiarity with Geovisualization

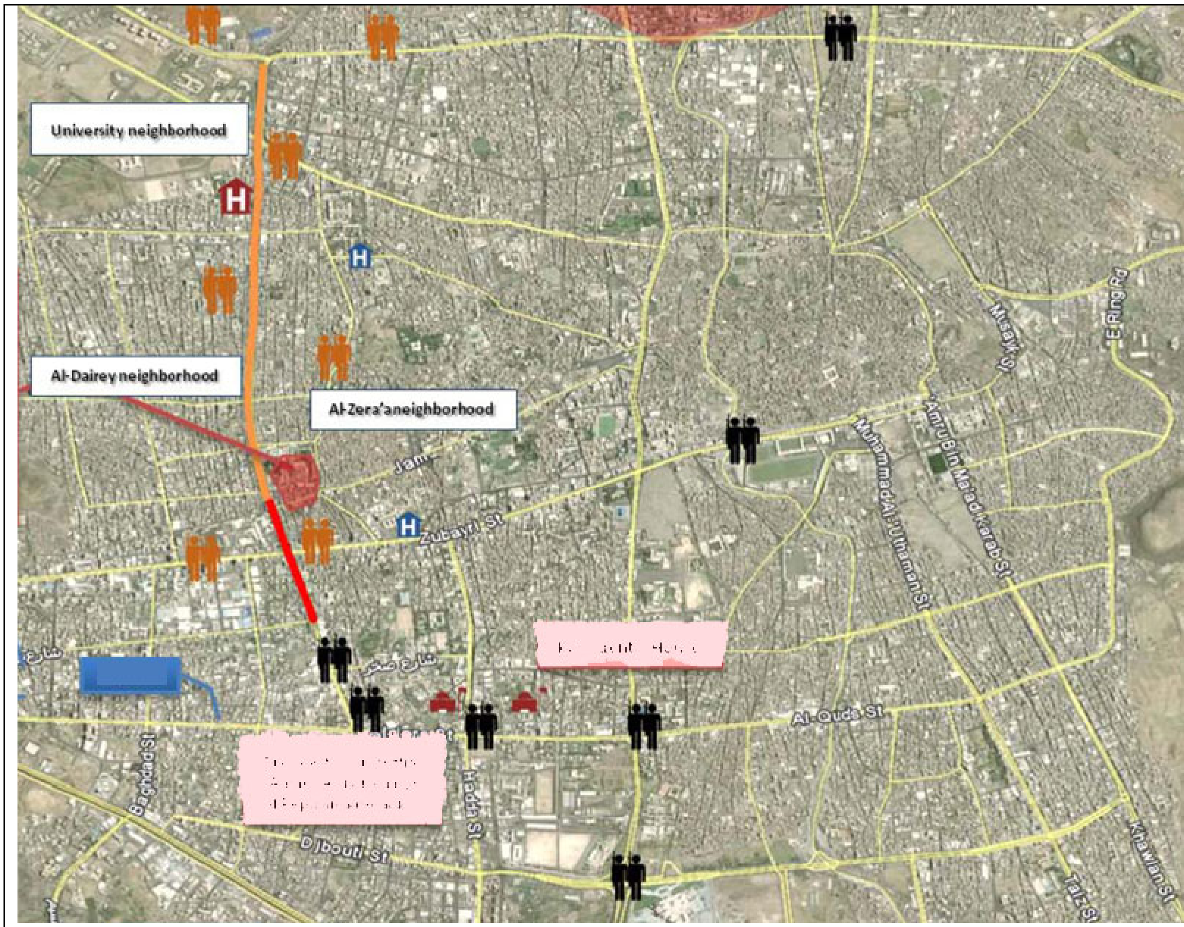


Figure 6.30 Geovizualiation for Orientation & Situation Reporting

Question 26.Geovisualization: The figure above shows how Geovisualization tools can be used to familiarize humanitarian workers with the terrain, infrastructure and hazards in a region. A user could also add his or her organization's internal activities to this analysis, perhaps to communicate status reports to co-workers, donors or other stakeholders. Compared to other methods of orientation and situation reporting, how useful is Geovisualization to you?

The humanitarian potential of web-based Geovisualization was first demonstrated in 2005, and by early 2007 had already been used to supplement coordination activities in numerous emergencies, ranging from Hurricane Katrina to the South Asian Earthquake, and from the Darfur Crisis to Yemen conflicts.

It was therefore not surprising that Question 25 showed a very high familiarity with Geovisualization amongst the humanitarian professionals that participated in the survey, nor unreasonable for three-quarters of them rate it as very useful or essential to making decisions during emergencies. As the figure below illustrates, only twelve of the survey respondents (9%) felt unsure or unconvinced about its utility, even though 24 survey respondents (18%) had earlier stated that they were unfamiliar with Geovisualization. It is possible that hype surrounding the "Google Earth phenomenon" has boosted the enthusiasm of even those who would admit to not fully understanding its potential. However even if one were to discount this as a factor, a clear majority of survey participants would want to use Geovisualization as a coordination tool during humanitarian emergencies.

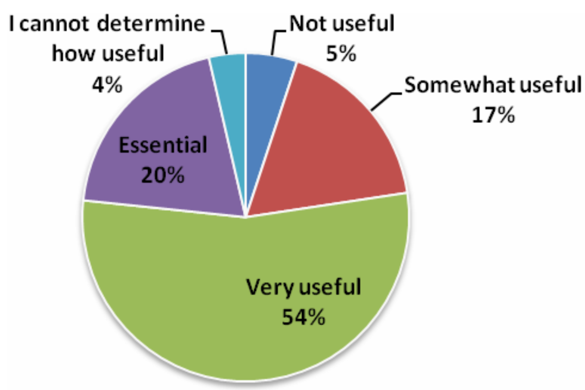


Figure 5.31 Utility of Geovisualization

What would be your ideal application(s) for this type of GIS-based analysis?

Common themes are summarized in the table5.18:

Table 5.18 Common Themes about Geovisualization

Common Themes	Repetitions
Optimistic	
To educate and communicate with field staff and stakeholders more effectively.	20
To simulate field conditions (for orientation or mission rehearsal)	16
To plan transportation strategies and access to remote sites.	13
To identify hazards, terrain and locations.	11
To coordinate humanitarian assistance through a "common operating picture"	8
This is the way for GIS to be exploited most effectively, and will be the way of the future.	4
Okay for headquarters staff but not for field-level planning decisions.	2
Skeptical	
Data quality, standards and internet connectivity are too unreliable for this to be used in most humanitarian emergencies at the field level.	6
Geovisualization consumes too much time and other resources to be critical.	3
Can be misleading since imagery does not reveal real-time conditions.	2

Although there was resounding eagerness for the use of Geovisualization, in a variety of typical coordination applications, the enthusiasm was tempered by valid concerns about data reliability, Internet dependency, and the fear that field-level information needs could not be met with tools like Google Earth.

Question 27. The following table lists the GIS-based analyses presented in this survey. Please review the list, and choose the top five types of analysis according to how useful they would be to you during humanitarian emergencies.

	First Choice				Fifth Choice
	1	2	3	4	5
Measurement (precise calculation of distance or area)	O	O	O	O	O
Cluster Analysis (investigating if certain phenomena (such as acts of violence) are related to other phenomena)	O	O	O	O	O
Site Selection (selecting potential camps, etc., based upon certain criteria)	O	O	O	O	O
Zone Analysis (analyzing the attributes of objects within a camp, district or other region of interest)	O	O	O	O	O
Central Feature Analysis (select the feature nearest to the middle of a set of features)	O	O	O	O	O
Service Optimization (determine the best location according to service goals, such as travel time or distance)	O	O	O	O	O
Gap Analysis (calculating shortfalls by comparing assessed needs with actual relief distributed)	O	O	O	O	O
Center Analysis (calculate the exact center of a set of weighted points)	O	O	O	O	O
Vulnerability Estimation (prediction of worst affected areas using buffer zones)	O	O	O	O	O
Route Optimization (selecting shortest or fastest route between 2 or more locations)	O	O	O	O	O
"What If?" Analysis (predicting the outcome of changes in the weather, relief distribution strategy, or other variables)	O	O	O	O	O
Range Analysis (analyzing the attributes of objects within a certain distance of another object)	O	O	O	O	O
Geovisualization (realistic, interactive portrayal and reporting of an affected region)	O	O	O	O	O

Figure 5.32 Top Five Types of GIS-Based Analysis (Survey Question 27)

The purpose of Question 27, the final survey question, was to cross-check prior responses and allows respondents to retrospectively calibrate their initial utility rankings. Question 27 also was an attempt to prioritize the top five types of analysis from the 13 examples provided.

Unfortunately, not all respondents completed the question correctly, and many selected more than five types of analysis in their response. Despite the researcher's attempts to prevent this from happening (through clear instruction and certain software features), only 87 (64%) of the 137 participants provided valid responses. Other survey participants provided responses that had to be excluded from the analysis, significantly reducing the calibrative impact originally anticipated from Question 27. "Invalid" responses were defined as those that: (a) were blank, (b) included more, or less, than five choices, or (c) attributed equal rank to more than one type of analysis.

Despite the large number of responses that needed to be excluded from the analysis, valuable insight about the relative utility of each type of GIS-base analysis can still be gleaned from the valid responses, as described below.

Table 5.19 Relative Utility of Each Type of GIS-Based Analysis (Question 27)

Type of GIS-Based Analysis[1]												
Statistics	Gap	Range	Zone	Measurement	Vulnerability Estimation	Site Selection	Service Optimization	Route Optimization	Exact Center	Cluster Analysis	What if	Geovisualization
Mean	**2.36**[2]	3	3.09	3.7	2.67	2.95	3.49	2.88	2.75	3.16	3.43	2.98
Standard Error	0.2	0.26	0.23	0.29	0.19	0.22	0.22	0.24	0.24	**0.19**	0.22	0.21
Median	**2**	3	3	4	2.5	3	4	3	2.5	3	4	3
Mode	**1**	2	4	5	**1**	2	4	3	4	3	5	4
Standard Deviation	1.495	**0.961**	1.279	1.302	1.387	1.446	1.292	1.191	1.165	1.347	1.434	1.511
Sample Variance	2.234	**0.923**	1.636	1.695	1.925	2.091	1.669	1.48	1.357	1.815	2.056	2.283
Skewness	0.711	0.607	-0.284	-0.49	0.367	0.179	-0.487	-0.076	-0.09	-0.093	-0.449	-0.036
Range	4	3	4	4	4	4	4	4	3	4	4	4
Minimum	1	2	1	1	1	1	1	1	1	1	1	1
Maximum	5	5	5	5	5	5	5	5	4	5	5	5
Sum	132	42	99	74	144	130	122	69	22	161	144	161
Count3	**56**	14	32	20	54	44	35	24	8	51	42	54

[1] Central Feature Analysis was the only type of GIS-based analysis not selected as a top-five choice by any survey participant, and therefore does not appear in the table.

[2] **Bold** values indicate the highest score for each metric and Red values indicate the highest score for key statistics.

[3] Defined as the frequency each type of GIS-based analysis was selected as a top-five choice, where n=87.

Table 5.19 provides descriptive statistics of the 87 valid responses collected by Question 27. Noting that a respondent's most favored type of analysis generated a score of 1 and his fifth most favored type of analysis generated a score of 5, the table depicts the popular utility of the various forms of GIS-based analysis. As indicated by the highlighted boxes, the most revealing statistics of mean, median, mode and count (i.e. frequency appearing as a top-five choice) all suggest that survey participants felt Gap Analysis was most useful to them during humanitarian emergencies. Without any doubt, GIS-based Gap Analysis was ranked to have the highest popular utility amongst the 87 participants who provided valid responses to Question 27. Second was Vulnerability Estimation, which validated the correspondingly strong response to Question 17 of the survey.

The comparative rank of the remaining types of analysis is less obvious, however based upon the key statistics of mean, median, mode and count, the researcher posits that Geovisualization, Cluster Analysis and Site Selection round out the top five ranking. In summary, Question 27 of the Phase 2 Quantitative Survey revealed that the following types of GIS-based analysis have the highest popular utility:

1. Gap Analysis
2. Vulnerability Estimation
3. Geovisualization
4. Cluster Analysis
5. Site Selection

Range Analysis generated an interesting score, both in terms of the key statistics and in terms of variance; although only 14 respondents (n=87) ranked it as a top-five choice, Range Analysis had the lowest variance, standard deviation, and the second highest mode. Simply put, those whom selected it did so with a remarkable consensus with regards to its relative utility. Cluster Analysis fared strongly in Question 27 but, in general, GIS-based statistics did not seem to be a high priority amongst survey respondents: Exact Center Analysis was the second to least frequent choice of survey respondents, outranking only Central Feature Analysis, which was not even selected once amongst the valid dataset. That does not mean that Geostatistics is useless, *per se*, but that it would appear to have much lower popular utility than other types of GIS-based analysis.

5.4 Analysis of Results

The Phase 4 survey attempted to elicit the views of a statistically-representative sample of the humanitarian community, in order to test the alternate questions proposed in Section 1.3. Before analyzing the results of the survey, it is important to once again acknowledge that an inherent characteristic of voluntary surveys is that they are not representative of the total population, only that portion interested in the topic being investigated. Extrapolating broad conclusions is only possible if the sample data is statistically-representative of the entire population, otherwise the use of inferential methods is risky.

In this thesis, the survey participants are representative of the target population *inclined to exploit GIS-based analysis*. In other words, the survey respondents **do** reflect the opinions of the relevant population since it would be unrealistic to measure the usefulness of GIS-based analysis across those who are disinterested in its application. Therefore, the researcher contends that the survey results produce a sufficient data set from which to infer the opinions of the target population, and that each of the alternative questions can be tested conclusively. Of course, a feasibility assessment would need to ensure that the population likely to exploit GIS-based analysis is sizeable enough to justify additional investments, but for the sake of determining utility, the self-selecting nature of the Phase 4 survey was not viewed as a limiting factor but as a true reflection of the potential user population.

Another major limitation of the survey was that it evaluated *speculative* utility of *representative* applications of GIS-based analysis. Put bluntly, not only was it impossible for the researcher to comprehensively test all possible applications, but their low dependency upon GIS required most respondents to predict how useful each of the examples would be to them during a humanitarian operation, if those analyses were available. Caution must therefore be employed in the interpretation of the survey results, since a more ideal dataset would have tested *proven* utility across a *full array* of applications.

Tables 5.20 compare the survey results presented in Section 5.3. The comparison displays how each type of analysis fared according to the metric of utility defined in Section 3.3.2: that is, a category of GIS-based analysis was defined as having a decisive impact if the total percentage of respondents rating it as “Essential” or “Very Useful” was 54% or greater. Except the Central Feature Analysis and Exact Center Analysis, because of many respondents were not confessed about these tools. The analysis is based upon a Confidence Level = 95%, Sample Size = 137 and Estimated Population = 10,000, which results in a Confidence Interval of 7.15%.

Table 5.20.1 Comparison of Survey Results (All Participants, n=137)

Category of GIS Based Analysis	Queries & Measurements			
	Gap Analysis	Measurement Analysis	Range Analysis	Zone Analysis
Essential	8%	17%	23%	33%
Very Useful	46%	40%	49%	40%
Somewhat Useful	31%	28%	17%	18%
Not Useful	9%	10%	4%	4%
N/A	6%	5%	7%	5%
Essential + Very Useful	54%	57%	72%	73%

Table 5.20.2 Comparison of Survey Results (All Participants, n=137)

Category of GIS Based Analysis	Transformations	
	Vulnerability Estimation	Site Selection
Essential	29%	29%
Very Useful	48%	51%
Somewhat Useful	10%	9%
Not Useful	8%	7%
N/A	5%	4%
Essential + Very Useful	77%	80%

Table 5.20.3 Comparison of Survey Results (All Participants, n=137)

Category of GIS Based Analysis	Optimizations	
	Service Optimization	Route Optimization
Essential	22%	11%
Very Useful	58%	51%
Somewhat Useful	14%	30%
Not Useful	2%	4%
N/A	4%	4%
Essential + Very Useful	80%	62%

Table 5.20.4 Comparison of Survey Results (All Participants, n=137)

Category of GIS Based Analysis	Geostatistics		
	Central Feature	Exact Center	Cluster

	Analysis	Analysis	Analysis
Essential	11%	15%	11%
Very Useful	18%	27%	54%
Somewhat Useful	51%	29%	15%
Not Useful	15%	15%	12%
N/A	5%	14%	8%
Essential + Very Useful	29%	42%	65%

Table 5.20.5 Comparison of Survey Results (All Participants, n=137)

Category of GIS Based Analysis	Hypothesis Testing	Geovisualization
	What if	Orientation & Simulation
Essential	21%	20%
Very Useful	49%	54%
Somewhat Useful	18%	17%
Not Useful	7%	5%
N/A	5%	4%
Essential + Very Useful	70%	74%

Irrespective of the underlying cause for this anomaly, it is fair to suggest that Gap Analysis is a key requirement to efficient coordination of humanitarian assistance, and that GIS-based analysis holds potential utility. However it would be too presumptuous, at this stage, to suggest the use of radial histograms is an effective means to calculate and portray those gaps. The utility of GIS becomes easier to imagine if standardized queries within a GIS could be used by coordinators to quickly identify and resolve inefficient distribution of relief in near real-time. But until the flow of humanitarian information improves transparency of humanitarian activity during an emergency, the calculation of gaps in relief distribution will be limited, and certainly doesn’t require GIS in order to be conducted.

Recalling that each type of GIS-based analysis needed to ranked as very useful or essential during humanitarian operations by at least 55% of the target population (within a confidence level of 95% and a confidence interval of 7.15%,) in order to have a decisive impact, this section concludes with a test of each of the secondary questions:

Secondary Question 1: Is Queries and Measurements Analysis can have a decisive impact upon the coordination of humanitarian assistance? Gap Analysis and Measurement Analysis passed the 54% threshold, and Range Analysis and Zone Analysis exceeded that threshold by a comfortable margin. Weighted with the calibration provided by Question 27 of the survey, we can conclude that this alternate questions tests positive.

Secondary Question 2: Is Transformation Analysis can have a decisive impact upon the coordination of humanitarian assistance? Vulnerability Estimation and Site Selection consistently ranked in the top five types of GIS-based Analysis, and well above the 77% threshold: we can safely conclude that this alternate question tests positive.

Secondary Question 3: Is Optimization Analysis can have a decisive impact upon the coordination of humanitarian assistance? Service Optimization scored very well and Route Optimization passed the 62% threshold, so we must conclude that Optimization Analysis can be useful. However, the lack of transportation network models necessary to perform optimizations combined with the marginal score of Route Optimization, suggest that this category of GIS-based analysis may not be feasible in the coordination of most humanitarian emergencies.

Secondary Question 4: Is Geostatistical Analysis can have decisive impact upon the coordination of humanitarian assistance? Cluster Analysis consistently scored within the top five types of GIS-based analysis, and we must conclude that this alternate question tests positive. However, the two other forms of geostatistical analysis scored very poorly, suggesting that some geostatistics may have very limited utility in the coordination of most humanitarian emergencies.

Secondary Question 5: Is Geovisualization <u>can have</u> a decisive impact upon the coordination of humanitarian assistance? It is safe to conclude from the very solid ratings for Geovisualization that it could become an essential tool for a broad spectrum of decision makers during humanitarian emergencies, particularly if it used to provide situational awareness as well as collect 3W data.

Secondary Question 6: Is Hypothesis testing and simulation analysis <u>can have</u> a decisive impact upon the coordination of humanitarian assistance? The survey scores allow us to conclude that this alternative question test positive, however the researcher cautions that the sophistication and range of applications for this category of GIS-based analysis merit a dedicated utility assessment in order to fully understand its potential.

The next chapter summarizes the overall findings of this thesis and provides this researcher's conclusions about the utility of GIS-based analysis as means to improve the coordination of humanitarian emergencies.

Chapter 6 – Summary & Conclusions

6.1 Summary of Research Findings

This thesis has examined whether GIS-based analysis can have a decisive impact upon the coordination of humanitarian assistance through the exploratory research method implemented in 5 phases suggested by this research.

Main impression was confirmed by an extensive interview survey of domain experts, who emphasized the long-standing need to create professional standards in data exchange and analysis that reflect the technologically-challenging field constraints encountered by UN and non-UN personnel during most humanitarian emergencies. The expert interviews also inspired a palette of GIS-based analyses deemed to have the greatest utility in promoting efficient coordination of humanitarian assistance; most prominent of that list of applications was Gap Analysis, which appears to be the most urgent and overdue information requirement needed to conduct efficient humanitarian coordination.

Based upon the findings of the expert survey, the researcher conducted a local survey of humanitarian professionals to test the utility of each category of GIS-based analysis. Simple examples of each category were developed to elicit opinion of how decisive each type of analysis was to the survey participants during a typical emergency. This statistically-representative sample population was then used to test a set of research questions, which investigated the utility of each category of GIS-based analysis based upon an arbitrary condition that a minimum of 55% of the target population, within a confidence level of 95% and confidence interval of 7.15%, rated at least one example from each category as being very useful or essential in their role as humanitarian professionals.

Based upon those results, it is possible to conclude that GIS-based analysis <u>can have</u> a decisive impact upon the coordination of humanitarian assistance. GIS offers substantial utility beyond its cartographic applications, most especially for analytical applications such as Site Selection, Geovisualization, Vulnerability Estimation, Cluster Analysis and Range Analysis. Even though the need for Gap Analysis seems indisputable, the qualitative and quantitative survey results produced by this thesis were inconsistent with regards to the application of GIS to conduct Gap Analysis, and more investigation will be required. More study will also be required in order to determine the utility of Hypothesis (i.e. “What if?”) Analysis, which appears promising but was simply too complex and varied to comprehensively assess in this thesis. The categories of Optimizations and Geostatistics appear to be least useful types of GIS-based analysis, and while they generated utility ratings above the prescribed 55% threshold, their ability to have a decisive impact to the coordination of humanitarian assistance seems comparatively limited.

6.2 Research Usefulness indicators

As it is known between the humanitarian community and international agencies, UNOCHA information products is playing big role to support the humanitarian coordination and assistance in the affected areas. UNOCHA office in Yemen is using the map concept to deliver the clear and right information for the decision makers and stockholders in Yemen. The Researcher job in UNOCHA Yemen as GIS specialist helped the office to produce the GIS maps and analysis since the beginning of 2010 till now , The research noticed the deceive impact of OCHA information products especially the Maps.

The maps and the GIS analysis changed the humanitarian actors’ strategies specifically in

1. Decision making
2. Information sharing
3. Use of the GIS tools and analysis
4. Partnership and Cooperation

There is a lot of humanitarian information products official issued by OCHA Yemen office which shows the enhancement of humanitarian coordination in Yemen. The implementation of the research method and researcher experience can also support the findings of the research. And here below showing some visual proving of the research findings. The next fact is based on the interviews on phase 3 and the researcher experience.

The indicators supporting the findings of the research are:

1. Growth of CAP funding and requirements of Yemen Humanitarian Response Plan

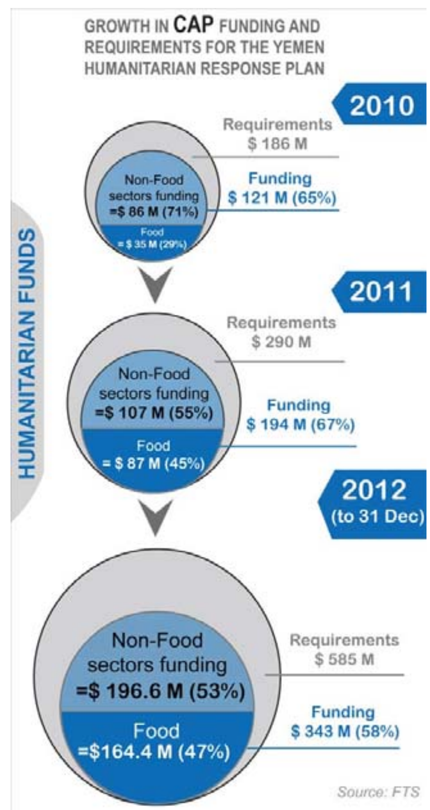


Figure 6.1 Growth of Humanitarian Funds in Yemen

2. Partnership between UN agencies, International and Local NGOs

Figure 6.2 Agencies Partnership in Yemen

3. Growth in Pooled funding (ERF- Emergency Response Fund), Annual Fund received

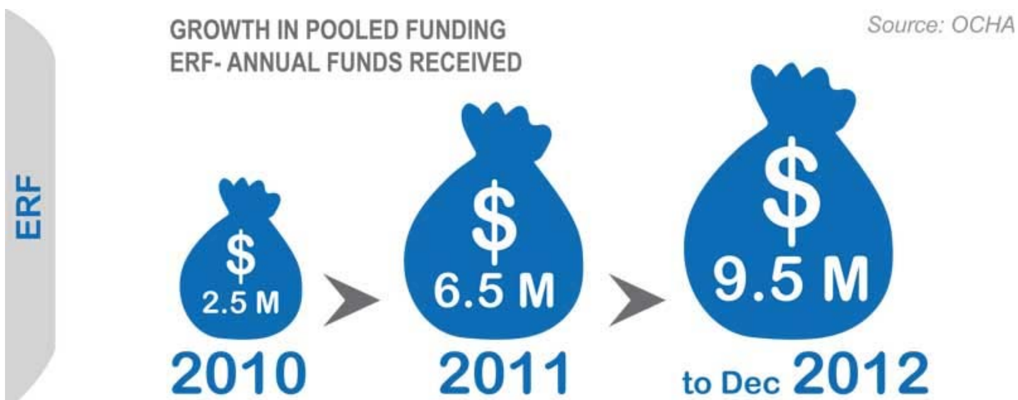


Figure 6.3 Growth of ERF Fund

4. Number of Humanitarian projects in Yemen on district level

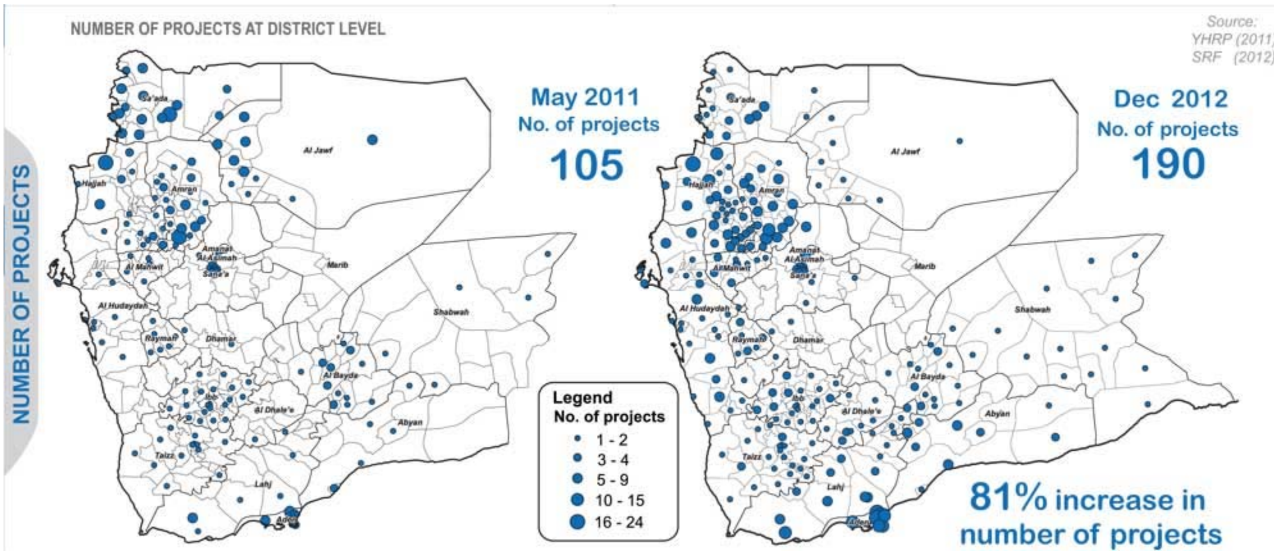


Figure 6.4 Growth of Humanitarian projects number in Yemen

5. Agencies participating in Yemen Humanitarian Response Plan

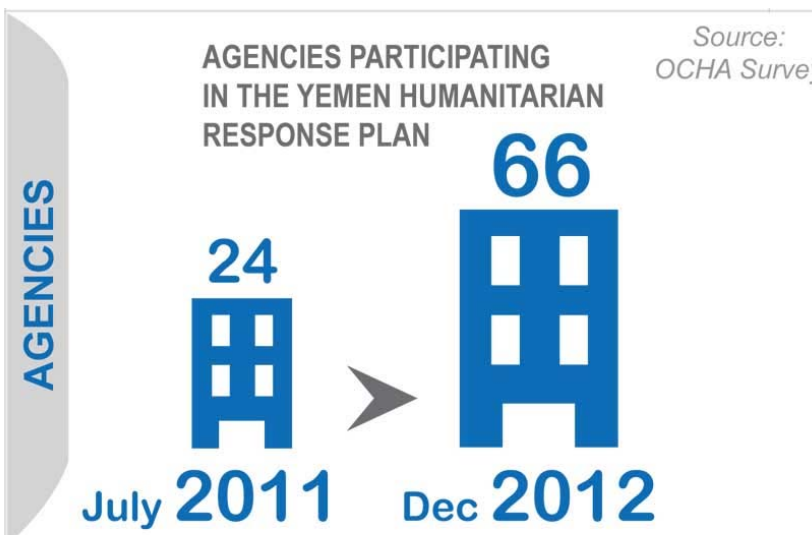


Figure 6.5 Number of Agencies participating in Yemen HRP

6. Number of ERF projects funded in Yemen

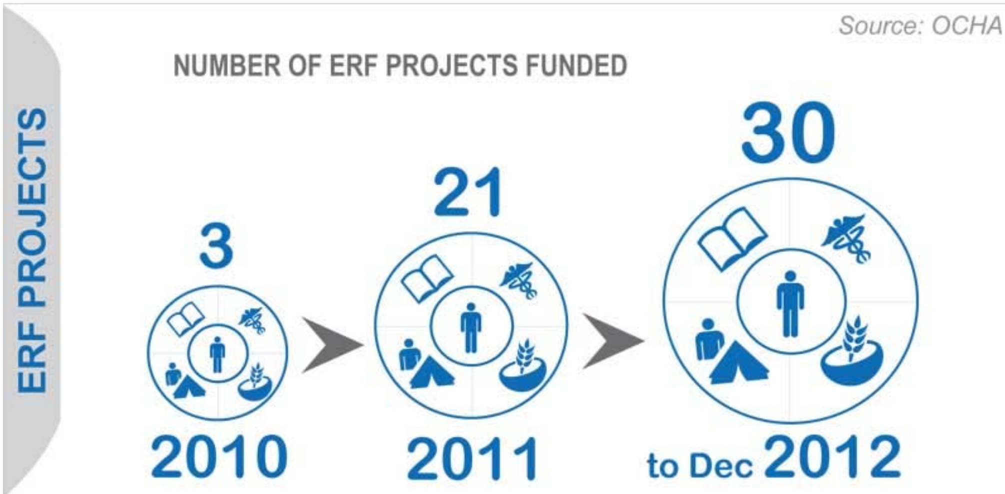


Figure 6.6 Number ERF projects funded in Yemen

6.3 Research Limitations

In addition to those limitations stated in sections 1.6.2, the mission of assessing the utility of GIS-based analysis to humanitarian coordination is complicated by the fact that the humanitarian community has negligible experience with analytical applications of GIS. Therefore, as already observed in section 4.4, the fundamental limitation of this research is that it primarily assesses the *speculative* utility of *potential* applications of GIS-based analysis, as opposed to the *proven* utility of *actual* applications. There is an inherent risk in presuming that humanitarian decision making will become highly dependent upon Cluster Analysis, or would remain indifferent towards Central Feature Analysis, based upon this thesis, if in reality, neither application has been widely-used to support the coordination of actual humanitarian emergencies. Put simply, there is no substitute for real-life validation of each category of GIS-based analysis if one wishes to reach a definitive conclusion about their utility!

And, it bears repeating that this was an assessment of utility, not feasibility. Nevertheless, the research conclusions will hopefully provide direction to theoreticians and practitioners, and present clues to which GIS applications offer the highest likelihood of improving the coordination of humanitarian assistance. That process must be conducted with very active involvement of the members of the UN Geographic Information Working Group and other contributors of GIS-based products and services, since only those organizations can ascertain their own ability to access the data and skills necessary to successfully produce GIS-based analysis during an emergency.

6.4 Recommendations for Further Research

Based upon the results of the literature review and the completion of this thesis, the author can offer five more recommendations for further research at a slightly more holistic level.

First, the broad consensus about the need to reduce the inefficiency of humanitarian relief distribution makes Gap Analysis the single-most important research application in this field. Every aspect of this topic needs to be investigated, not only in terms of GIS-based analysis, but also how to collect and compare (1) Needs Assessment and (2) Who-What-Where (3W) data in a timely and reliable manner. This is not an original recommendation, and humanitarian professionals have lamented for a long time about this issue, however the continued failure to establish the standards and methods to conduct Gap Analysis is unacceptable when one contemplates the implications of inefficient relief operations on disaster victims. Gap Analysis should therefore be considered as not only top-priority research topic, but also one of the most exciting potential applications of GIS.

The second recommendation for further research relates to the need to better understand the utility of web-based GIS and mobile technologies as a means to not only inform clients effectively, but to also facilitate the interactive collection of *humanitarian data by the coordinators at the same time*. There is significant merit to examining how tools like Google Earth or GPS-enabled mobile phones can make it easier for busy field staff to report any activities and events while obtaining updates for themselves. It is unrealistic to continue to expect that overwhelmed field staff will interrupt their primary responsibilities to submit detailed reports about their activities to the UN Humanitarian Coordinator. Therefore, effortless reporting mechanisms should become another major thrust of research and experimentation, since they could play a major part in improving situational awareness during humanitarian emergencies.

Third, there is clearly a need to simplify the process of collecting, analyzing and disseminating humanitarian information given the stressful context of most humanitarian emergencies. One of the Phase 3 survey participants made a strong impression on the researcher when he demanded that UNOCHA not introduce new products or services during the chaos of an emergency, and that it exploit pre-existing systems approaches already know by the Cluster lead agencies as well as the non-UN humanitarian community. When new products or services are developed, methods to introduce their use before an emergency should be examined, so that beneficiaries can learn how to exploit them well in advance of being expected to depend upon them during a crisis. Further research, by scholars and practitioners alike, is recommended to learn if and how various forms of GIS-based analysis can be incorporated into the on-going stream of routine information products so that at the time of an emergency, responders already have an appetite for, and knowledge how to use, those types of analyses.

Fourth, the researcher advises the use of collaborative research to develop a doctrine capable of supporting GIS-based humanitarian coordination, so that *sophisticated applications of GIS-based analysis can become operationally feasible.*

Research by humanitarian organizations, academia and the private sector is needed to accelerate the creation of standards, data models, cartographic symbology, analytical methods, and data exchange forums. Such research partnerships should also strive to establish a post-secondary curriculum capable of producing humanitarian professionals skilled in the theoretical and practical applications of GIS. The Emergency Capacity Building project (referred to in section 2.3.3) revealed a remarkably mild appetite for systematic, disciplined and quantitative humanitarian information management even amongst the most sophisticated NGOs. Poor doctrine and an absence of systems-engineered approaches explain the perennially weak ability to overcome humanitarian coordination challenges. Fortunately, the new generation of humanitarian professionals is already prone towards the use of technologies such as the Internet and handheld computers, making this an ideal time to develop systems-engineered "good practices" in humanitarian coordination and, implicitly, GIS.

Finally, further research is recommended in the issue of automation. As data standards and information-sharing mechanisms evolve, it may become increasingly possible to create partially and totally-automated routines to produce the standard array of cartographic and analytical products expected during any UN-led humanitarian emergency, relieving humanitarian coordination staff to concentrate on performing customized analyses relevant to each specific emergency. At present, highly-skilled GIS specialists appear to be overwhelmed by mundane mapping exercises and data processing tasks, instead of producing meaningful, customized "geo-intelligence" – a tremendous waste of their talent and limited availability. The development of automated forms of map-making and analysis would also improve product consistency, and if embedded within web-based GIS tools, presents an outstanding opportunity to transcend the barriers in GIS exploitation that exist today within and beyond the UN's Humanitarian Information Centers.

6.5 Conclusions

In this examination of whether GIS can be useful to support the coordination of humanitarian assistance, the answer is a qualified "yes". Some categories of GIS-based analysis offer strong potential to make a decisive impact during an emergency, however there is simply insufficient real-life experience to conclusively determine if even the most promising applications, such as Site Selection or Vulnerability Estimation, would be as useful as suggested by this thesis, or that the least promising applications, such a Central Feature Analysis or Route Optimization, would be as impotent.

This thesis, therefore, is just one (albeit important) step towards articulating, testing and then evaluating the actual utility and feasibility of GIS-based analysis. What is clear, however, is that there is vast opportunity to take better advantage of the data, technology and skills already being used to conduct cartographic applications of GIS during humanitarian emergencies. The challenge therefore is to seek every avenue to leverage existing GIS programs and to continuously improve the overall coordination of humanitarian relief activities through more disciplined and systems-engineered solutions, and through more scholarly research and doctrine that reflects the importance of the ultimate objective of humanitarian assistance.

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APPENDIX A: QUANTITATIVE SURVEY INVITATION

Survey to investigate the effectiveness of GIS- based analysis towards the Coordination of Humanitarian Assistance in Yemen

Dear colleague,

You are invited to take part in a survey being conducted by The St. Clements University in Sana'a. The survey supports a doctoral thesis aimed at improving the coordination of humanitarian assistance in Yemen during international emergencies.

You are being asked to take part in this thesis because of your experience in humanitarian assistance and disaster management. You do not need any GIS expertise to participate – the survey provides simple examples which will allow you to judge whether GIS-based analysis can be useful during humanitarian emergencies.

Your participation is entirely voluntary, and all responses will be collected and analyzed anonymously.

Thank you and kind regards,

Najib Al-Mansour

APPENDIX B: QUANTITATIVE SURVEY

1. What type of organization do you work for? Choose the best response:	
o Non-Governmental (International)	o United Nations
o Non-Governmental (Local)	o Academic / Research
o Donor Agency	o Private Sector
o Government	o Other (please specify):

2. What is your primary role/responsibility in your organization? Choose the best response:	
o Communications & Public Relations	o Program Manager
o Senior Manager / Policy Maker	o Relief Worker
o Researcher	o Technician
o Donor Development / Management	o Monitoring & Evaluation
o Desk Officer / Analyst	o Other (please specify):

3. What is the geographic focus of your work in Yemen? Select all that apply:	
o All Governorates	o Areas of Conflicts
o Northern Part	o Areas of Natural Disasters
o Southern Part	o Other
o Central Part	

4. Which humanitarian cluster(s) best describe your primary area(s) of expertise? Select no more than 3 from the list below:	
o Camp Management /Emergency Shelter	o Health
o Cluster Coordination	o Protection
o Early Recovery	o (WASH) Water & Sanitation
o Education	o Food
o Nutrition	o Other (please specify):

5. How many years of experience do you have within the field of humanitarian Assistance?
o <1
o 1-5
o 6-10
o 11-15
o 16-20
o >20

6. How would you rate your expectations (i.e. interest) in the humanitarian applications of Geographic Information Systems (GIS)?
o None (Skeptical)
o Low (Cautious)
o Moderate (Curious)
o High (Optimistic)

7. How would you rate your understanding of GIS?
o Poor
o Basic
o Good
o Excellent

8. How would you rate your level of training in GIS? Training can be formal (classroom, workshops, etc.) or informal (on-the-job, self-taught, etc.)
o None
o Basic
o Intermediate
o Advanced
o Expert

9. How often do you use or depend upon GIS during humanitarian emergencies? Consider past experience either as an actual user of GIS, or as a beneficiary of GIS products/services produced by others.
o Never
o Occasionally
o Frequently
o Daily
o Other (please specify):

10. What sources of GIS products and/or services do you use during humanitarian emergencies?
o Not applicable / Not sure
o Public sources (e.g. ReliefWeb, Humanitarian Information Centers, etc.)
o Private sources (e.g. internal GIS staff or consultants, etc.)
o Both public AND private sources
o Other (please specify):

11. Do you believe that GIS currently has a decisive impact upon the international coordination of humanitarian assistance?
o No
o Yes
o Not sure

12. Even if it may not currently, do you believe that GIS could have a decisive

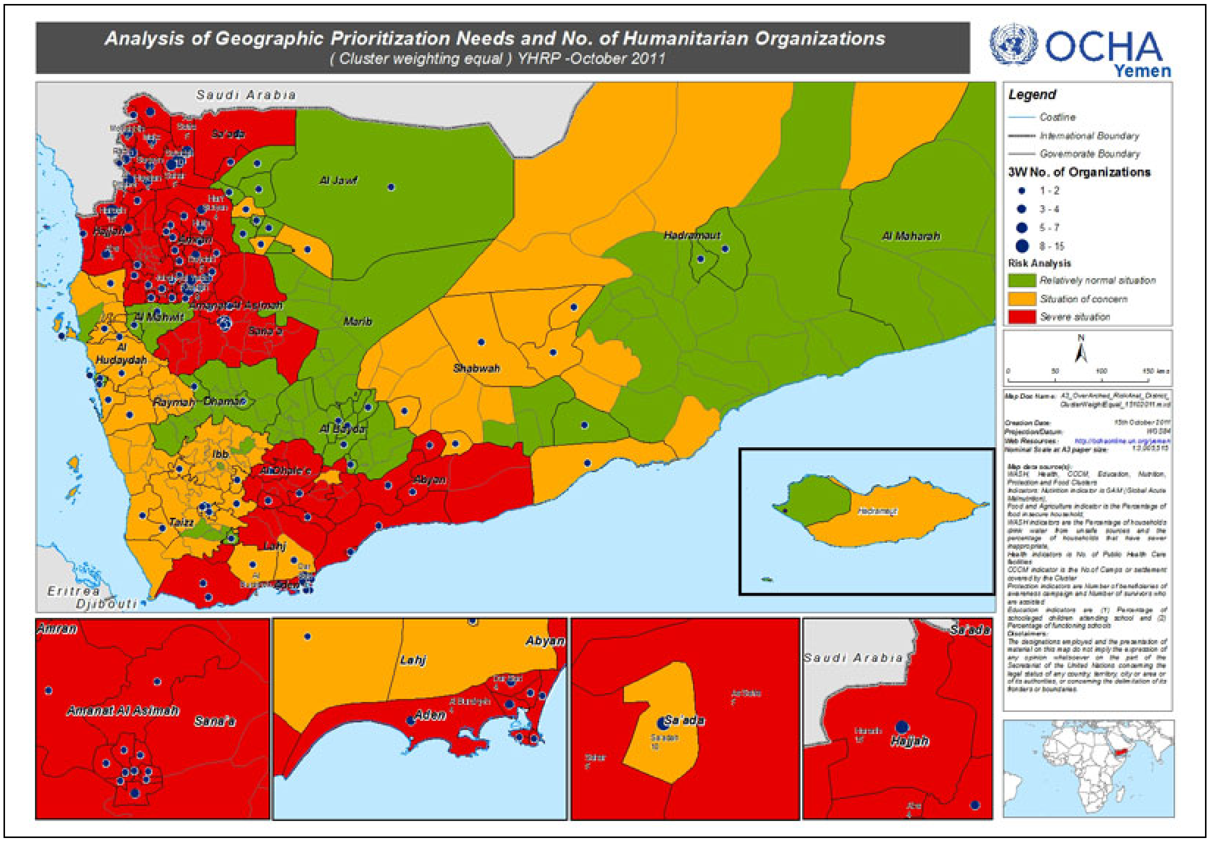
impact upon the coordination of humanitarian assistance (in the future)?
o No
o Yes
o Not sure

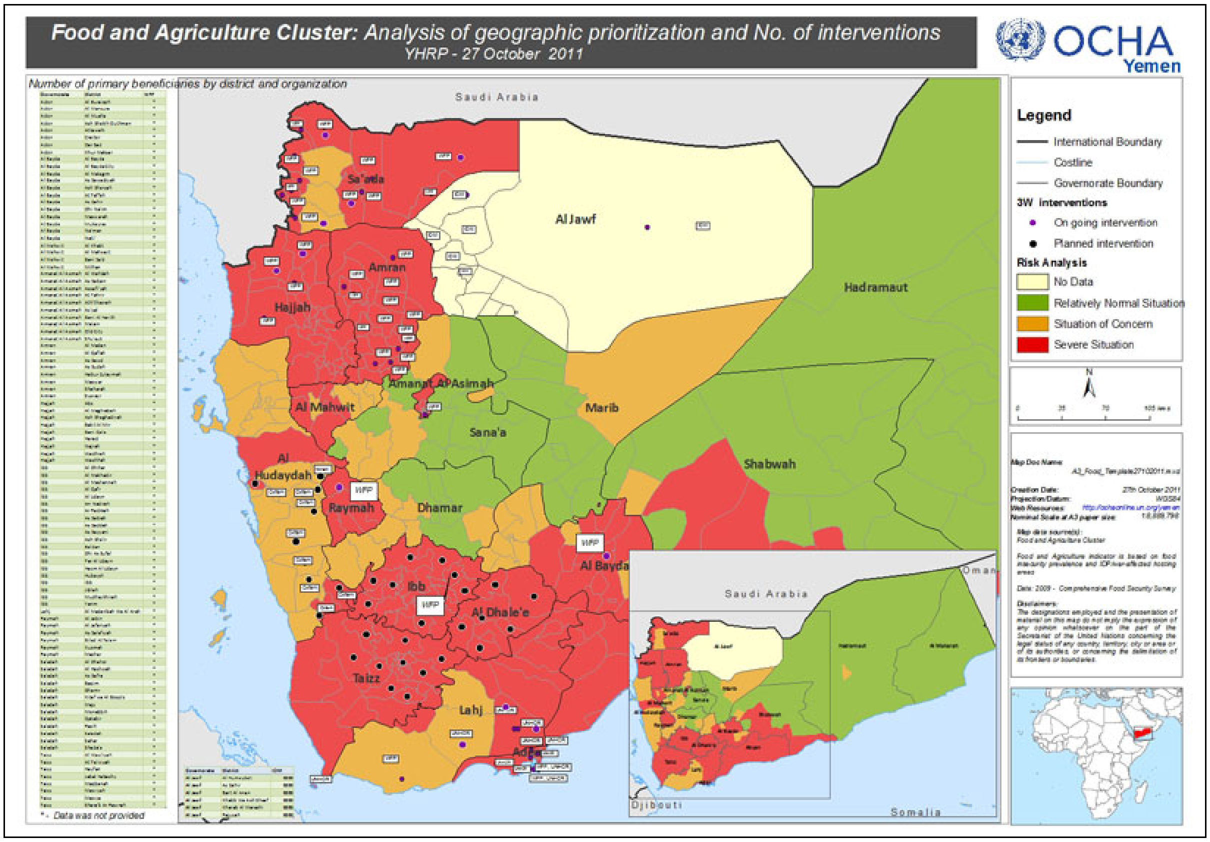
Explain why or why not:

TYPES OF GIS-BASED ANALYSIS

Instructions: For each of the following questions, indicate how useful each type of GIS-based analysis would be to you during a humanitarian emergency. Completely ignore the availability of data, skills or time necessary to complete the analysis - assume that they exist and are not limiting factors. Also, remember that all figures are simply intended to illustrate the survey questions -

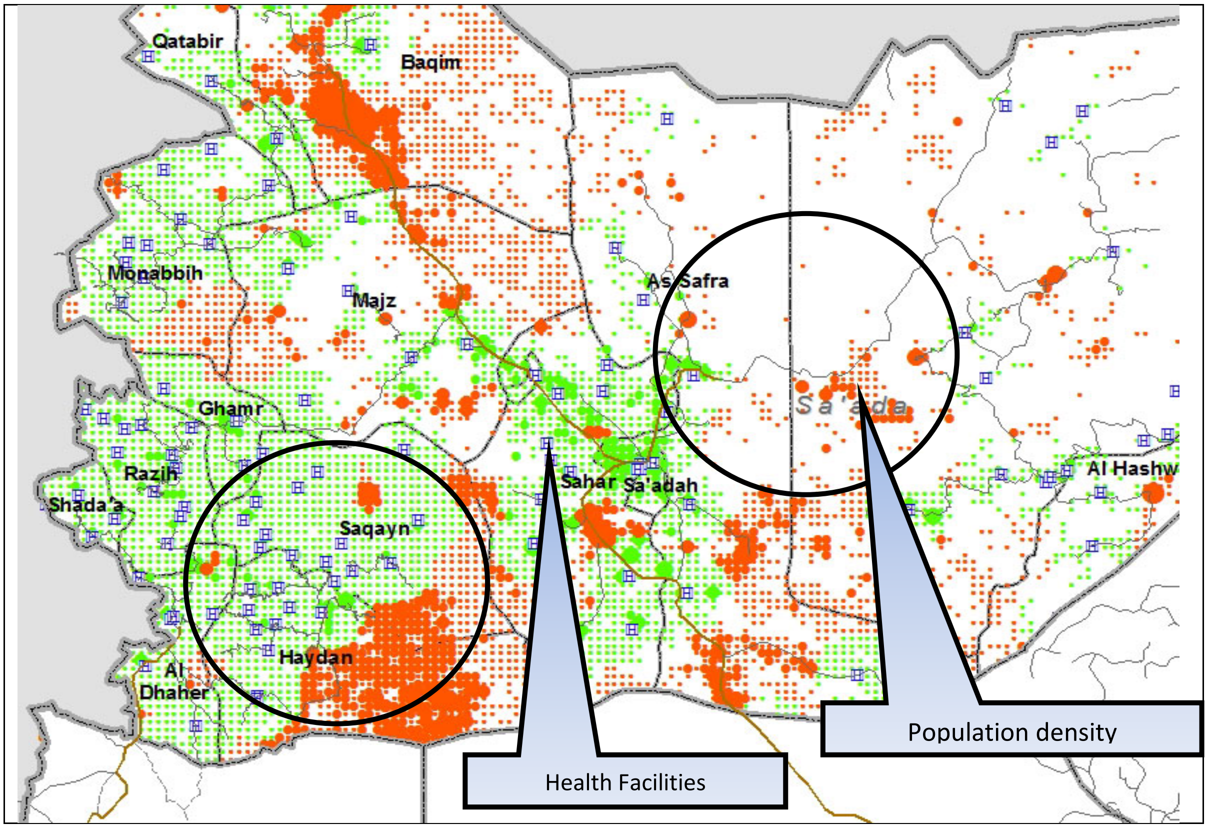
substitute and complicate the examples according to your typical application(s) before answering.
FIRST read each question and thesis the supporting illustrations.
THEN consider how your work might exploit the proposed analysis.
FINALLY indicate *how useful* that type of analysis would be if you could use it during a relief operation.
Note: You are evaluating the TYPE of analysis, not the specific example! Please take a moment before answering to reflect upon how these types of analysis could be applied within your ideal application(s).





13. Gap Analysis: The figures above show gaps in the distribution of humanitarian relief over time. Compared to existing methods of tracking the progress of humanitarian response, how useful is this type of analysis to you? Gaps would be calculated through periodic comparison of Assessed Needs and Who-What-Where data. Original base maps produced by OCHA Yemen (March 2011)
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

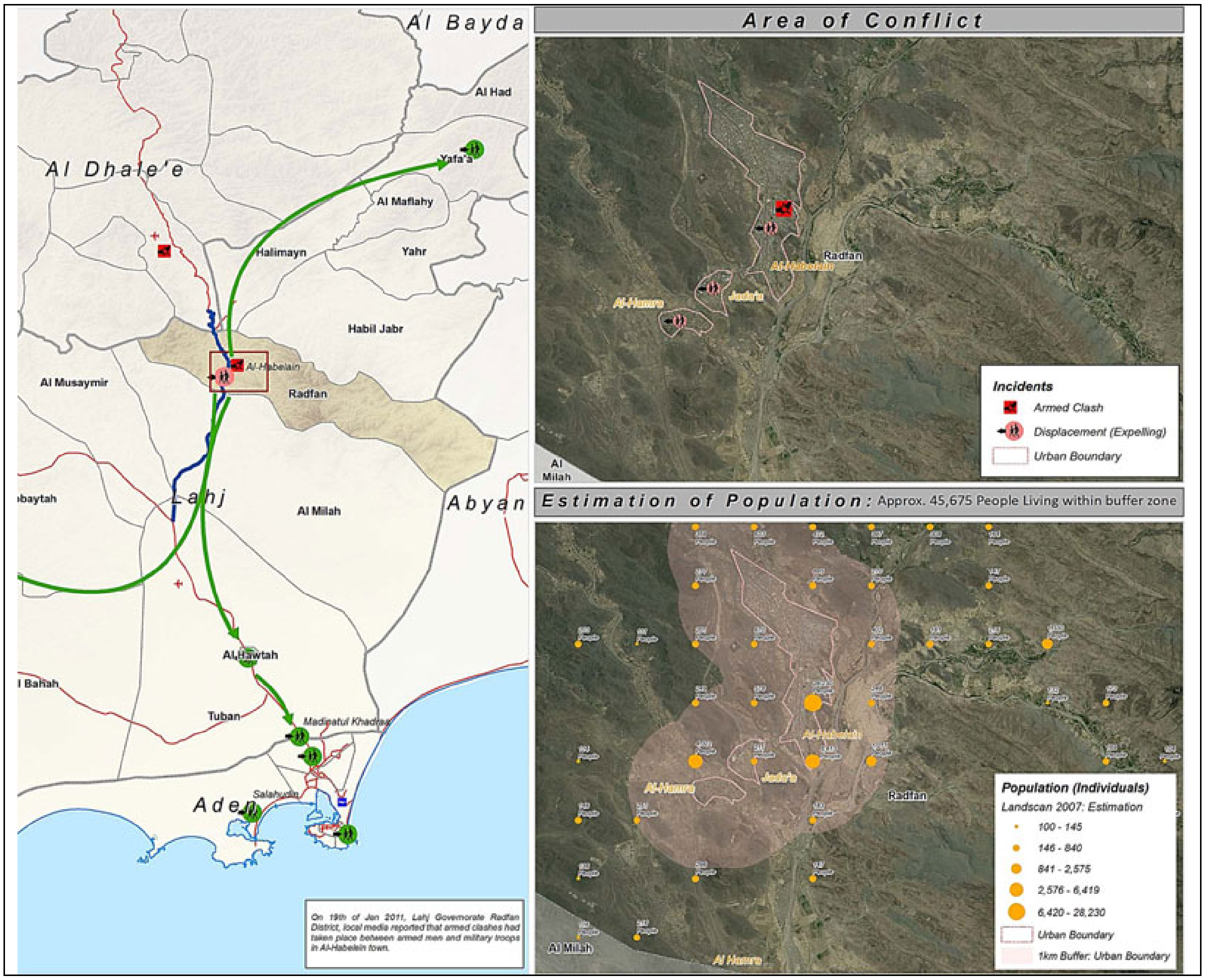
How would this type of analysis affect your decision making?



14. Range Analysis: The figure above shows how GIS can be used to calculate the number of settlements (or schools, hospitals, people, etc.) within a certain distance of a vaccination clinic (or road, food distribution point, etc.). How useful is this type of analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

REMEMBER: You are evaluating the TYPE of analysis, not the specific example! Ignore cartographic presentation, and
focus only upon how these types of analysis might support your decision-making during humanitarian emergencies.

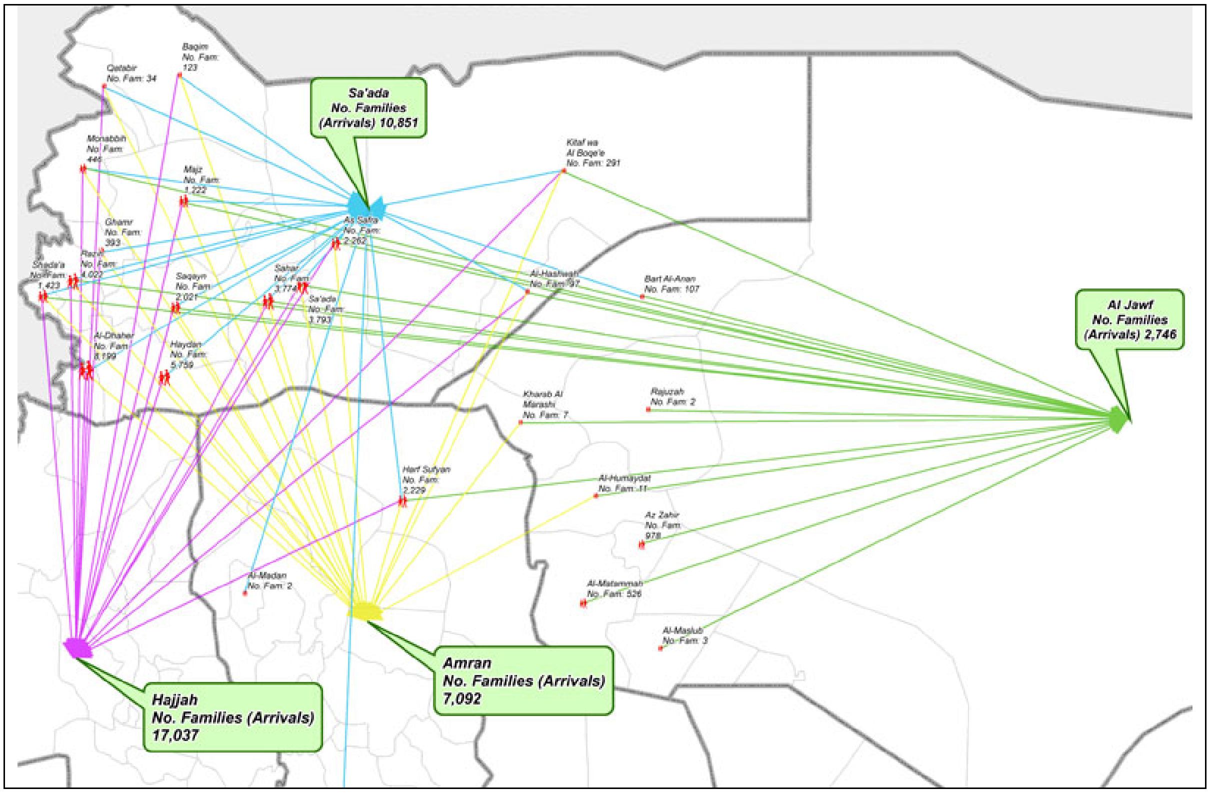
What would be your ideal application(s) for this type of GIS-based analysis?



15. Zone Analysis: The figure above shows how GIS can be used to calculate the total
relief capacity (and compliance with humanitarian standards) within a certain area. How useful is this type of analysis to you?

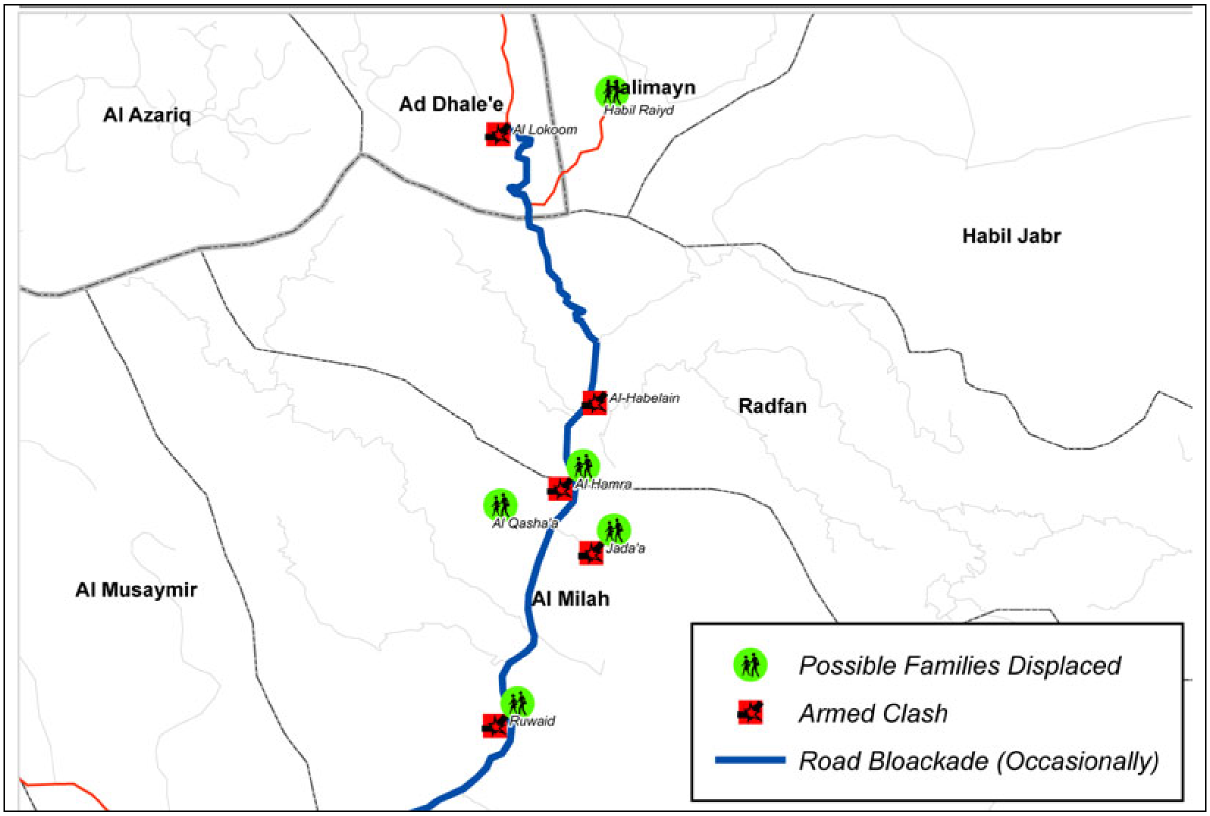
- o Not useful
- o Somewhat useful
- o Very useful
- o Essential
- o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



16. Measurement: The figure above shows how GIS can be used to measure the straight-line or driving distance between two locations. It also shows how it can be used to calculate the areal extent of certain features - this can be useful to approximate volumes of pesticide for anti-malarial spraying, or estimating resource potential of farmland or forests. Compared to existing methods of distance and areal measurement, how useful is this type of GIS-based analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



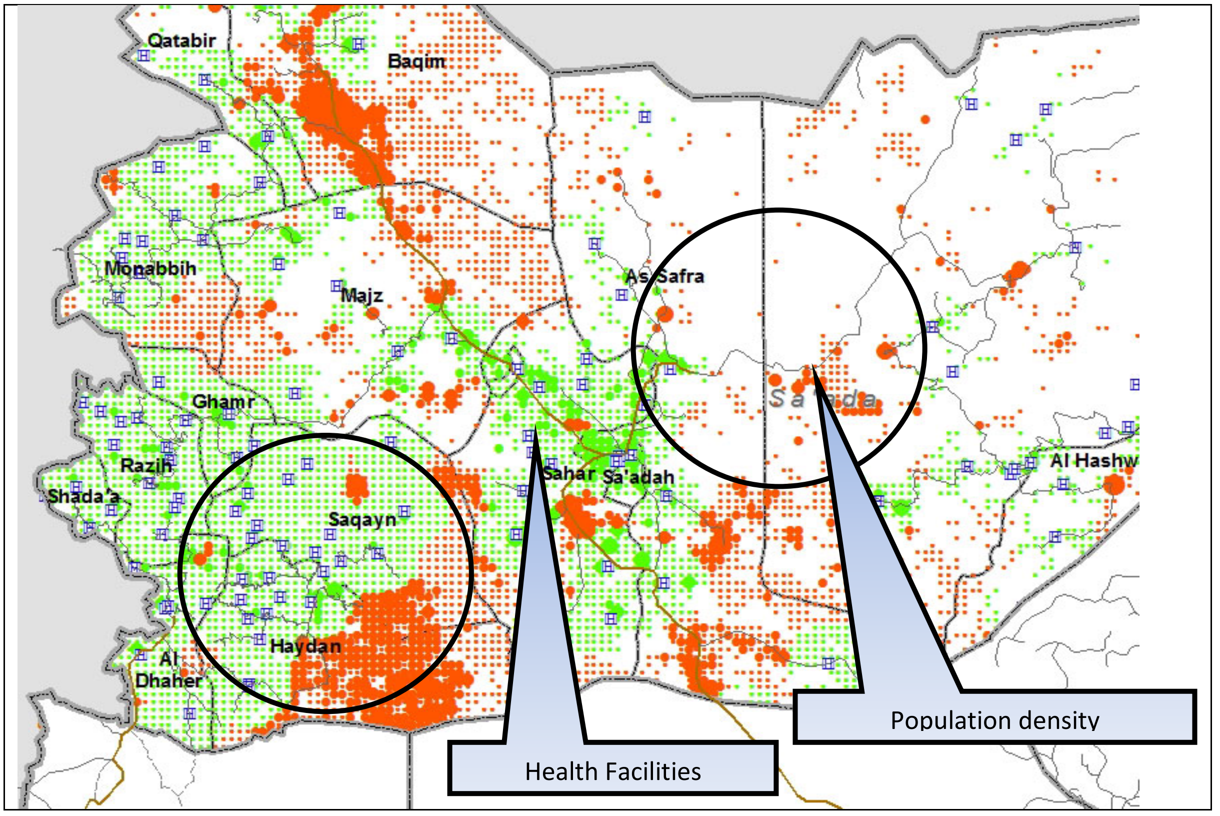
17. Vulnerability Estimation: The figure above shows how GIS can be used to estimate the areas worst affected by armored conflict. Populations that are most vulnerable to receiving inadequate relief are anticipated, based upon their distance to main routes, local capitals, territorial boundaries, and ongoing relief activity. Compared to existing methods of vulnerability estimation, how useful is this type of analysis (called "buffer analysis") to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?

18. Site Selection: GIS can be used to identify the best locations for campsites (or schools, hospitals, helipads, etc.), based upon certain criteria such as water availability, land cover, accessibility, hazards, etc. In other words, by layering

existing knowledge of landcover, terrain, hydrology and relief activities, it is possible to apply GIS-based analysis to optimize the locations for relief operations. How useful is this type of analysis to you? (Note: there is no illustration associated with this question.)
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



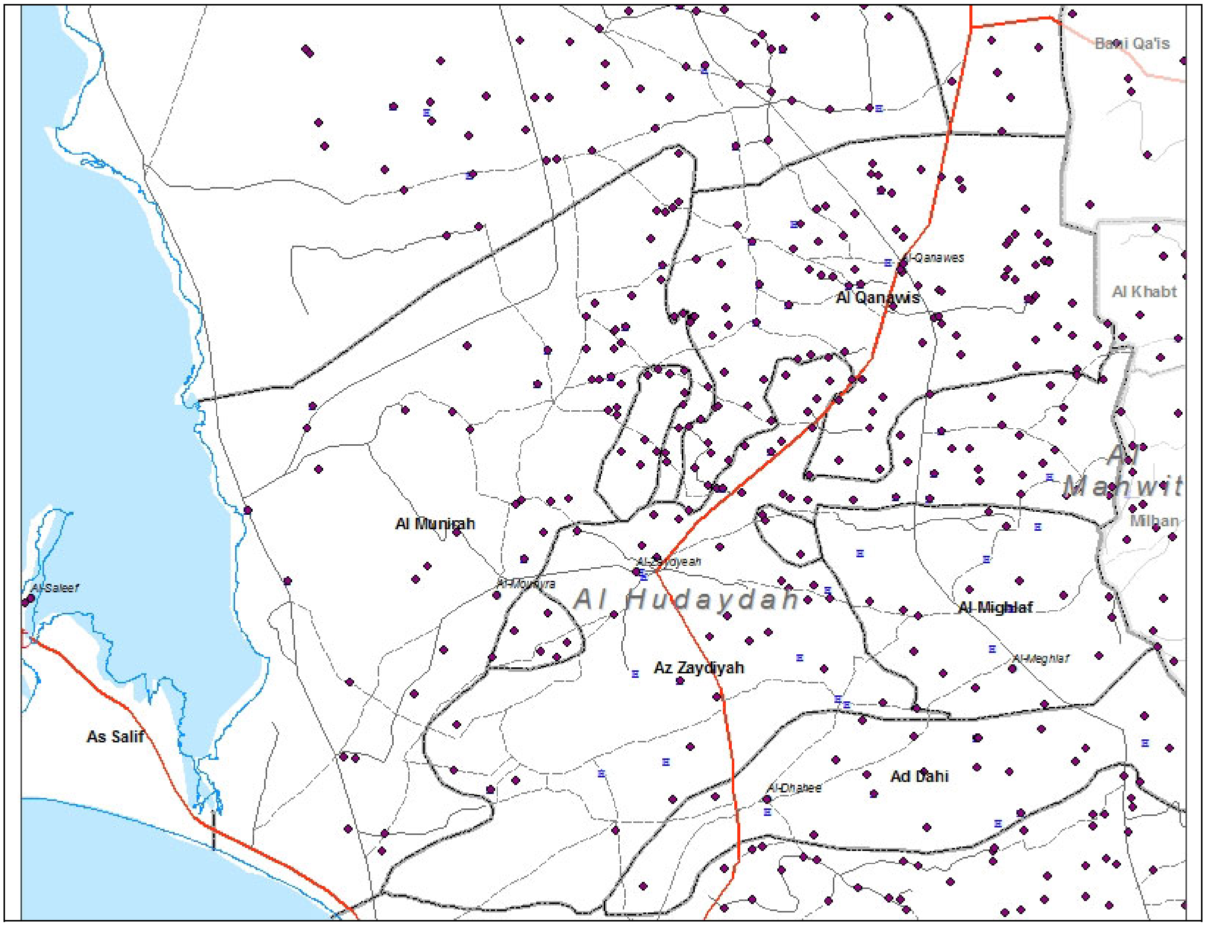
19. Service Optimization: The figure above shows how GIS can be used to determine the best locations to service a dispersed population, based upon certain travel goals. Compared to existing methods of service optimization, how useful is this type of analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

REMEMBER: You are evaluating the TYPE of analysis, not the specific example! Ignore cartographic presentation, and focus only upon how these types of analysis might support your decision-making during humanitarian emergencies.

What would be your ideal application(s) for this type of GIS-based analysis?

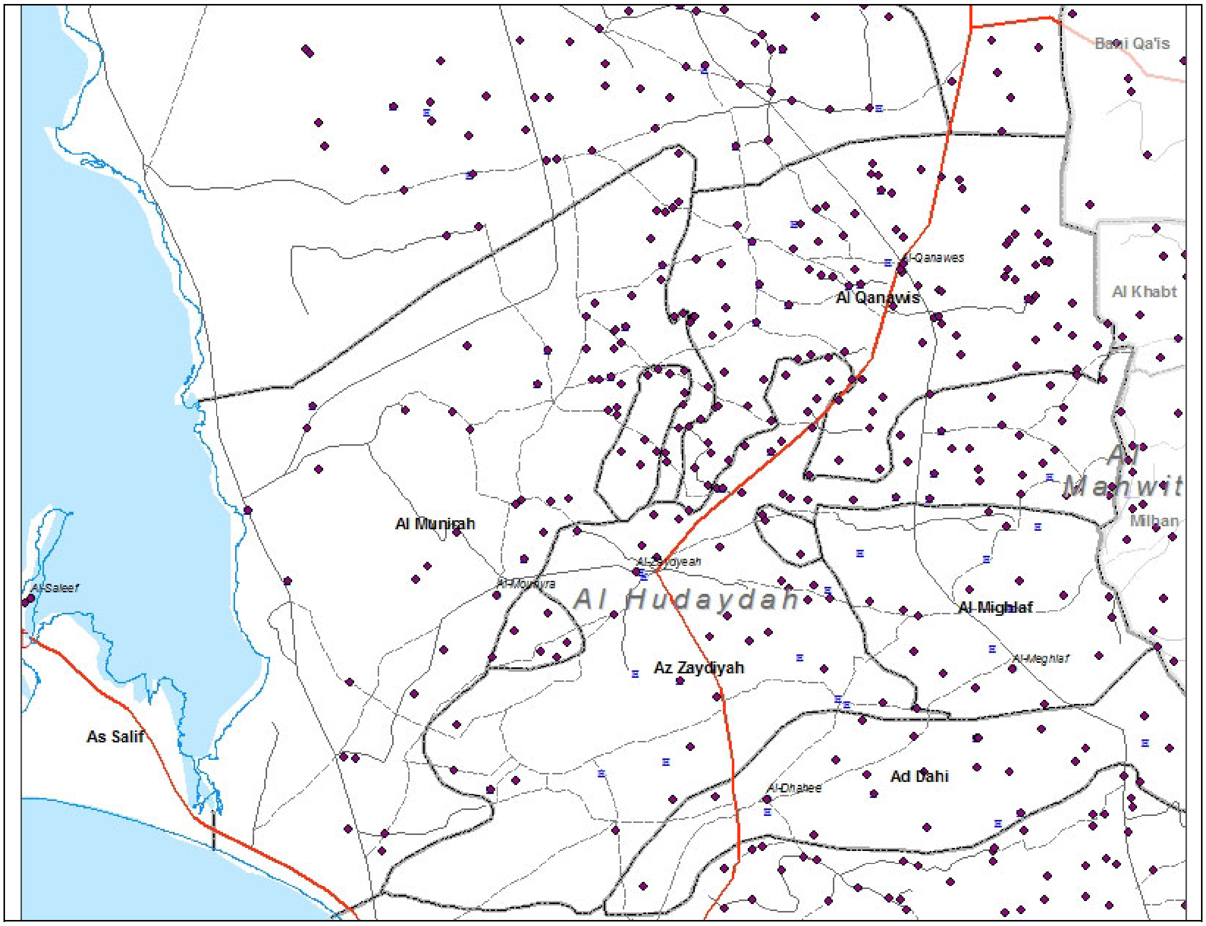
20. Route Optimization: You may be familiar with Internet-based route planning services, which allow the user to input an origin and destination and then obtain a turn-by-turn set of directions. When transportation networks are complex (or constantly changing), GIS-based analysis can quickly identify the shortest or fastest route between two or more locations. Compared to existing methods of navigation and route planning during humanitarian operations, how useful would this type of analysis be to you? (Note: there is no illustration associated with this question.)
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



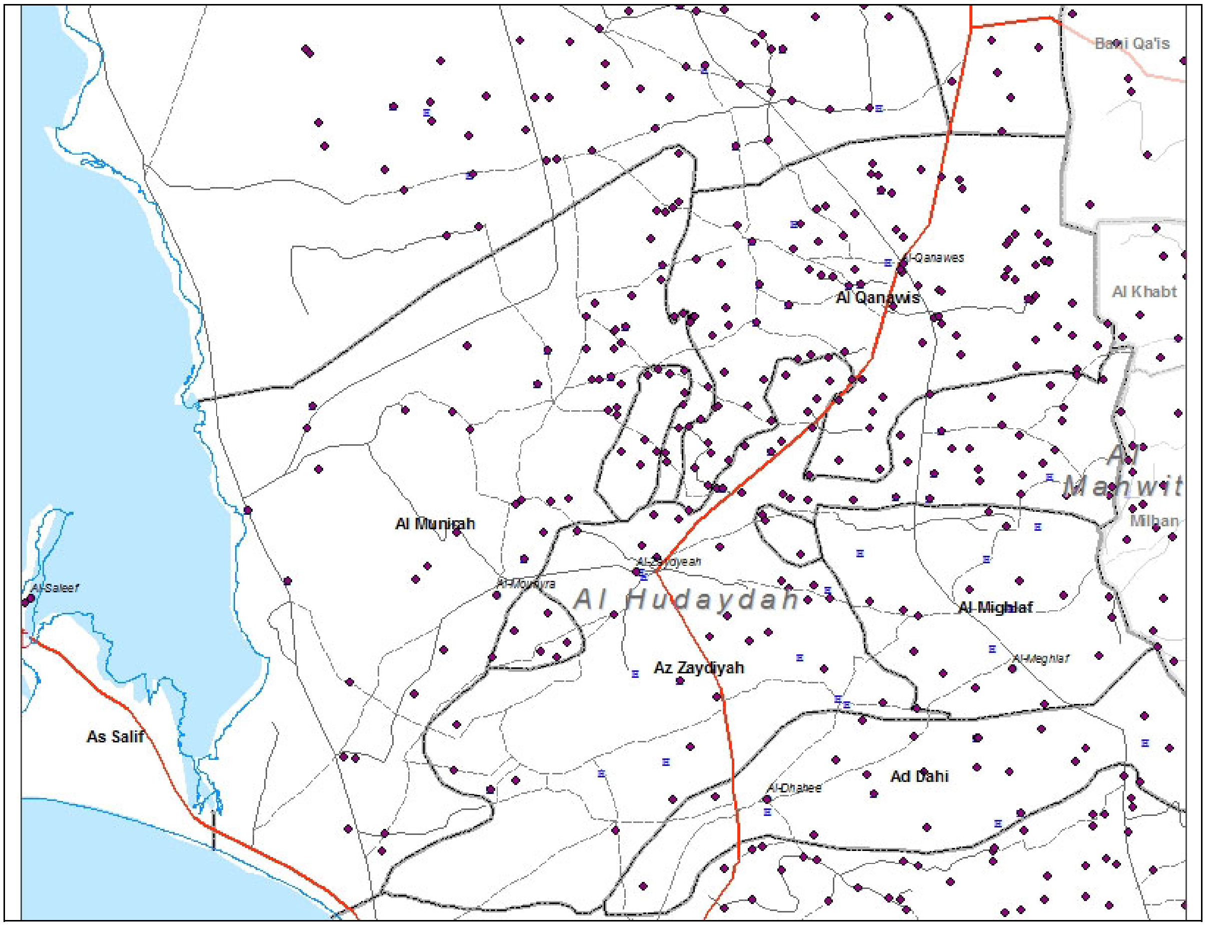
21. Central Feature Analysis: The figure above shows how GIS can be used to calculate the most central point amongst a set of unweighted points (which might represent villages, vacant office buildings, etc.). Compared to other methods of finding the best location to establish relief operations, how useful is this type of analysis to you? Note: this is the geostatistical equivilant of the "median" amongst the set of points.
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



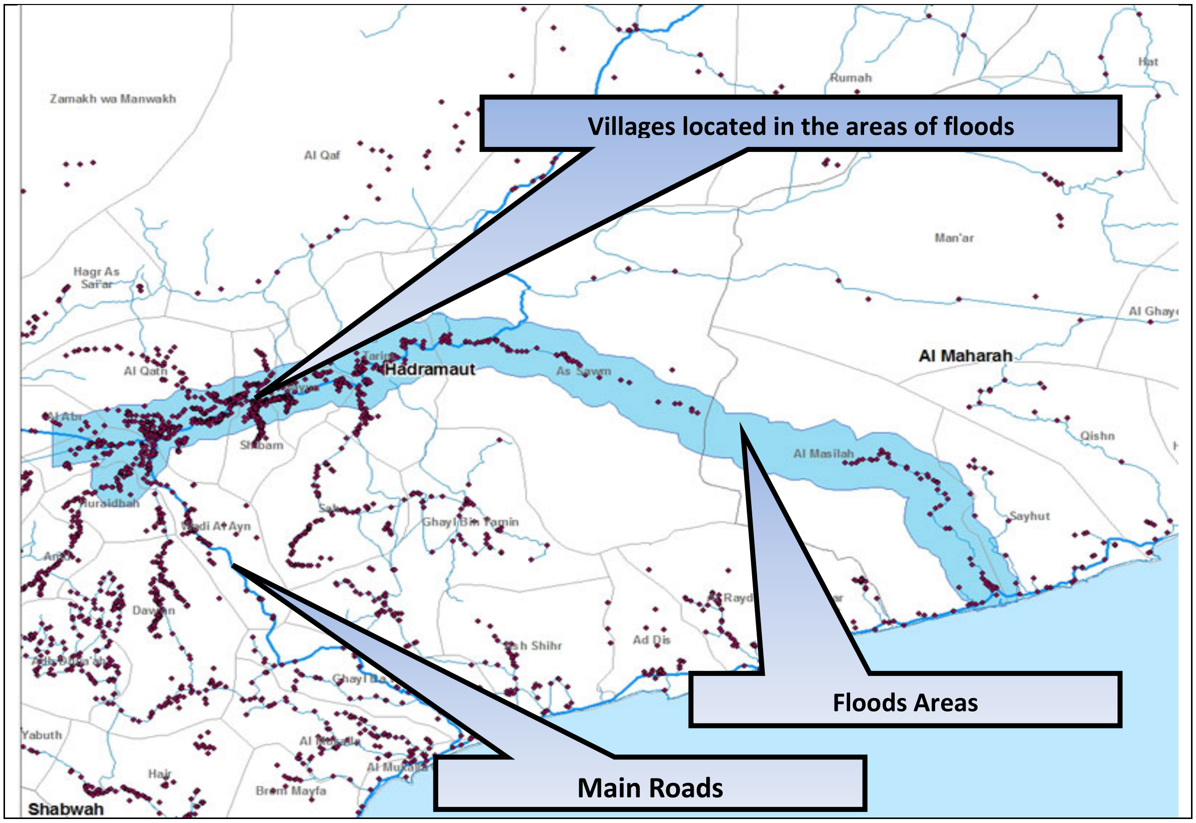
22. Exact Center Analysis: The figure above shows how GIS can be used to calculate the exact center amongst a set of points (weighted to reflect village populations, agricultural output, AIDS/HIV infection rates, etc.). Compared to existing methods, how useful is this type of analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



23. Cluster Analysis: The figure above shows how GIS can be used to identify if a series of features is correlated (i.e. clustered) with other phenomena. The purpose of cluster analysis is to determine if the distribution of a set of features is related or random, and to investigate cause-and-effect relationships. The most common applications of cluster analysis have been in epidemiology (detecting possible sources of disease outbreaks) and crime analysis (anticipating the location and tactics of criminals). How useful is this type of analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?



24. "What if" Analysis: GIS can be used to simulate how changes in one or more variables might impact a humanitarian relief operation. For example, the figure above illustrates the extent of floods in Hadramout Governorate (Yemen) ; by simulating different levels of floods, it could be possible to predict changes in road accessibility and relief needs at different elevations. Another example of this type of GIS-based analysis is the prediction of human migration patterns based upon relief locations, weather patterns or security trends. Of course, such types of analysis are complex and inherently prone to error. How useful is this type of analysis to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for this type of GIS-based analysis?

25. Are you familiar or do you use web-based geovisualization tools such as Google Earth, Microsoft Virtual Earth or ArcGIS Explorer?
o No
o Yes

GEOVISUALIZATION

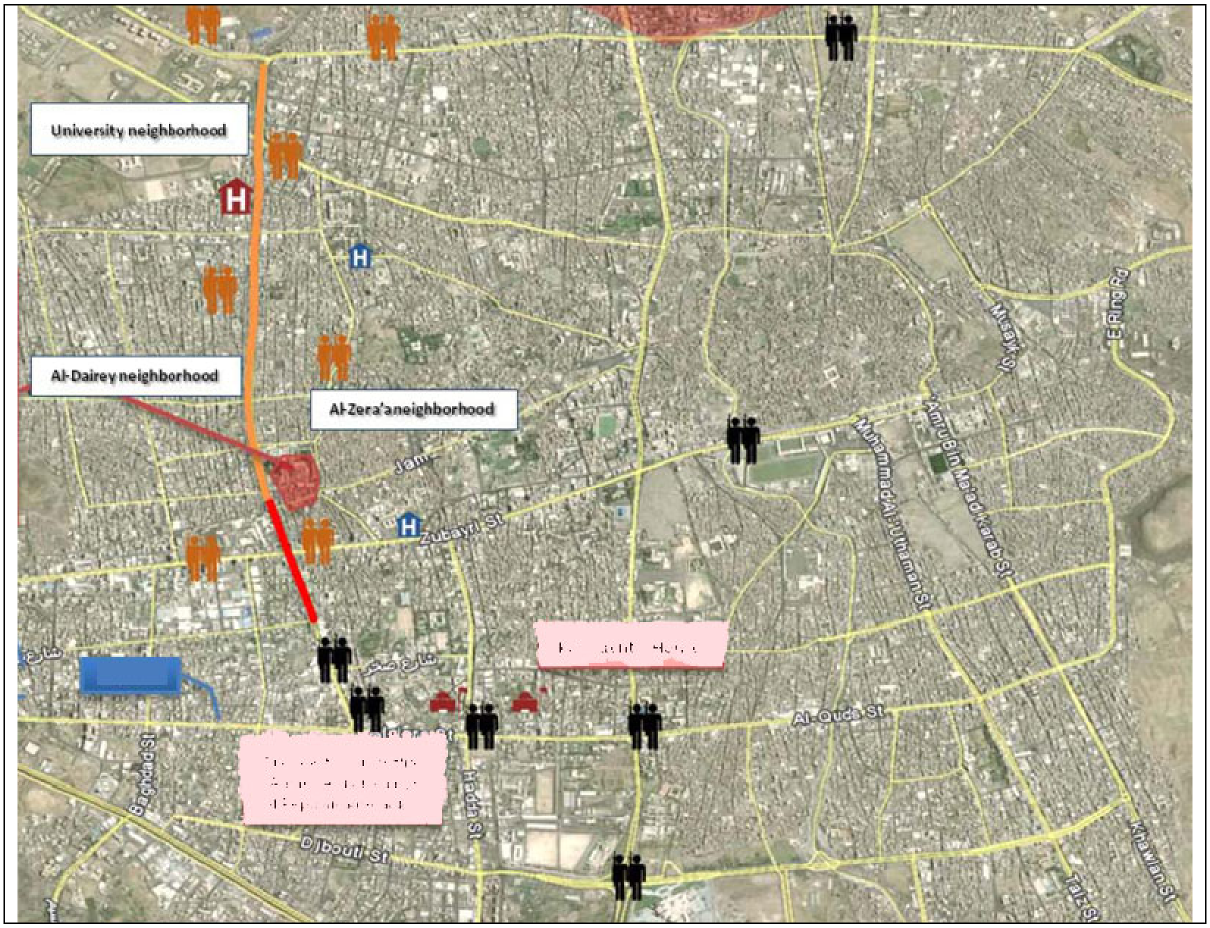
"Geovisualization" is an interactive method of communicating geographic and non-geographic information, simply and realistically. It helps users understand the world's surface in three dimensions and in high-resolution, (i.e. from the same perspective as low-altitude flight).

Some humanitarian organizations are now using geovisualization tools (such as Google Earth), since they allow almost anyone with a high-speed Internet connection to interact, create and publish geospatial data quickly, without much training, and at no cost. Prior to these “streaming” Web-based services, the expense and skill necessary to create this type of experience was prohibitive even for the largest UN and non-UN organizations.

Ongoing software advancements provide greater functionality and user-orientation; it is now possible for a non-specialist to use geovisualization tools to input organizational data, conduct common types of analysis, and produce customized maps easily and efficiently.

The primary limitation of geovisualization is that users must have computer access and high-speed Internet connectivity. Another disadvantage is that the imagery and data provided by free services are not necessarily up-to-date, and base data can sometimes be unreliable for critical decision making.

Providing a "common operating picture" can be challenging during humanitarian emergencies, and geovisualization may offer a new means for organizations to communicate efficiently in the chaotic aftermath of a disaster.



26. Geovisualization: The figure above shows how geovisualization tools can be used to familiarize humanitarian workers with the terrain, infrastructure and hazards in a region. A user could also add his or her organization's internal activities to this analysis, perhaps to communicate status reports to co-workers, donors or other stakeholders. Compared to other methods of orientation and situation reporting, how useful is geovisualization to you?
o Not useful
o Somewhat useful
o Very useful
o Essential
o I cannot determine how useful (i.e. I defer to other experts OR this question is not clear to me)

What would be your ideal application(s) for geovisualization?
27. The following table lists the GIS-based analysis presented in this survey. Please review the list, and choose the top five types of analysis according to how useful they would be to you during humanitarian emergencies.

	First Choice				Fifth choice
	1	2	3	4	5
Measurement (precise calculation of distance or area)	O	O	O	O	O
Cluster Analysis (investigating if certain phenomena (such as acts of violence) are related to other phenomena)	O	O	O	O	O
Site Selection (selecting potential camps, etc., based upon certain criteria)	O	O	O	O	O
Zone Analysis (analyzing the attributes of objects within a camp, district or other region of interest)	O	O	O	O	O
Central Feature Analysis (select the feature nearest to the middle of a set of features)	O	O	O	O	O
Service Optimization (determine the best location according to service goals, such as travel time or distance)	O	O	O	O	O
Gap Analysis (calculating shortfalls by comparing assessed needs with actual relief distributed)	O	O	O	O	O
Center Analysis (calculate the exact center of a set of weighted points)	O	O	O	O	O
Vulnerability Estimation (prediction of worst affected areas using buffer zones)	O	O	O	O	O
Route Optimization (selecting shortest or fastest route between 2 or more locations)	O	O	O	O	O
"What If?" Analysis (predicting the outcome of changes in the weather, relief distribution strategy, or other variables)	O	O	O	O	O
Range Analysis (analyzing the attributes of objects within a certain distance of another object)	O	O	O	O	O
Geovisualization (realistic, interactive portrayal and reporting of an affected region)	O	O	O	O	O

Any additional comments or suggestions?

APPENDIX C: Samples of Collected Data

جدول رقم (4) السكان المقيمين في الجمهورية حسب النوع والمحافظات (بالألف)

Table No. (4) Resident Population in Republic by Sex and Governorate (000)

Governorate	2011**				2010**			2009**			2008**			2007**			2006**			2005**			2004*			المحافظات
	نسبة النوع Sex %	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	إجمالي Total	إناث Females	ذكور Males	
Ibb	95	2,560	1,312	1,248	2,490	1,275	1,215	2,422	1,240	1,182	2,355	1,204	1,151	2,289	1,170	1,120	2,225	1,136	1,089	2,162	1,102	1,059	2,132	1,088	1,044	إب
Abyan	104	528	259	269	512	251	261	497	244	253	483	237	246	468	230	239	454	223	231	440	216	225	434	213	221	أبين
Sana'a City	124	2,153	960	1,193	2,088	932	1,155	2,023	904	1,118	1,959	877	1,082	1,896	850	1,046	1,835	824	1,011	1,775	798	977	1,748	786	962	امانه العاصمة
Al-Baida	102	695	344	351	675	334	341	657	325	332	638	316	323	621	307	314	603	298	305	586	289	296	577	285	292	البيضاء
Taiz	92	2,885	1,505	1,379	2,805	1,463	1,342	2,727	1,421	1,306	2,651	1,380	1,270	2,576	1,340	1,236	2,502	1,301	1,201	2,429	1,262	1,168	2,393	1,243	1,150	تعز
Al-Jawf	118	532	244	288	517	237	280	503	230	273	489	224	266	476	218	258	463	211	251	449	205	244	444	203	241	الجوف
Hajjah	108	1,782	856	926	1,732	832	900	1,684	808	875	1,636	785	851	1,590	763	827	1,545	741	804	1,501	719	782	1,480	709	771	حجة
Al-Hodeidah	106	2,621	1,275	1,346	2,545	1,238	1,307	2,471	1,202	1,269	2,398	1,166	1,232	2,327	1,131	1,196	2,258	1,097	1,160	2,191	1,064	1,126	2,158	1,048	1,109	الحديدة
Hadramout	106	1,255	608	647	1,218	590	628	1,182	573	609	1,147	556	591	1,112	539	573	1,079	523	556	1,046	507	539	1,029	498	530	حضرموت
Dhamar	98	1,603	810	793	1,558	787	771	1,514	764	750	1,472	743	729	1,430	721	709	1,390	700	689	1,350	680	670	1,330	670	661	ذمار
Shabwah	106	568	275	293	552	267	285	537	260	277	521	252	269	507	245	262	492	238	254	478	231	247	470	227	243	شبوة
Sa'adah	107	838	405	433	815	393	421	792	382	409	769	371	398	747	361	387	726	350	376	705	340	365	695	335	360	صعدة
Sana'a	103	1,109	546	564	1,078	530	548	1,048	515	533	1,019	501	518	990	486	504	962	472	489	934	458	476	919	451	468	صنعاء
Aden	114	731	341	390	707	330	377	684	320	365	662	310	352	640	300	341	619	290	329	599	280	318	589	276	314	عدن
Laheg	99	875	439	436	850	427	423	826	414	412	802	402	400	779	390	389	756	379	377	734	367	367	723	362	361	لحج
Mareb	115	288	134	154	280	130	149	272	127	145	264	123	141	257	120	137	249	116	133	242	113	129	239	111	127	مأرب
Al-Mahweet	100	597	298	299	580	289	291	564	281	283	548	273	275	532	265	267	517	257	260	502	250	253	495	246	248	المحويت
Al-Maharah	120	108	49	59	105	48	57	102	46	55	99	45	54	96	44	52	93	42	50	90	41	49	89	40	48	المهرة
Amran	105	1,061	517	544	1,031	502	529	1,002	488	514	974	474	500	946	460	486	919	446	472	892	433	459	878	426	451	عمران
Al-Daleh	105	569	278	291	553	270	283	537	262	275	522	255	267	507	247	259	492	240	252	478	233	245	471	229	241	الضالع
Reymah	95	475	244	231	461	237	225	449	230	219	436	223	213	424	217	207	412	211	202	400	204	196	394	201	193	ريمة
Total	104	23,833	11,699	12,133	23,154	11,364	11,790	22,492	11,037	11,455	21,844	10,716	11,127	21,209	10,402	10,807	20,590	10,095	10,495	19,983	9,794	10,189	19,685	9,648	10,037	الإجمالي

* Census 2004

** Population Projections of the Republic of Yemen (2005-2025)

* تعداد 2004

** الإسقاطات السكانية للجمهورية اليمنية للفترة (2005-2025)

Table No. (4) جدول رقم (4)

	District	عدد المحلات No. of Sub Village	عدد القرى No. of Village	عدد الحارات No. of Harah	عدد الأحياء No. of Hai	مراكز مديريات Districts Centers	العزل No. of Sub District	المديرية	م
1	Old Sana'a	0	0	69	1	0	0	صنعاء القديمة	1
2	Shu'ub	0	0	101	12	0	0	شعوب	2
3	Azaal	0	0	34	6	0	0	آزال	3
4	Al-Safyah	0	0	20	1	0	0	الصافية	4
5	Al-Sabe'ein	0	0	78	15	0	0	السبعين	5
6	Al-Wehdah	0	0	34	9	0	0	الوحدة	6
7	Al-Tahreer	0	0	36	3	0	0	التحرير	7
8	Maeen	0	0	97	3	0	0	معين	8
9	Al-Thawrah	0	0	48	8	0	0	الثورة	9
10	Bani Al-Hareth	125	52	153	8	1	3	بني الحارث	10
	Sana'a City Outskirts - Hamdan	0	0	43	8	0	0	ضواحي الامانة جزء من مديرية همدان	
	Sana'a City Outskirts - Sanhan,Bani Bahlawl	0	0	78	15	0	0	ضواحي الامانة جزء من مديرية سنحان وبني بهلول	
Total	No. of Districts: 10 Governorate Center: 1	125	52	791	89	1	3	مركز المحافظة: 1 عدد المديريات: 10	إجمالي المحافظة

* According to the final results of 2004 census

طبقاً للنتائج النهائية لتعداد 2004م *

نسبة الفقر العام بحسب المحافظات والحالة الحضرية

Ratio of Poverty by Governorates and Urban Status

Table No (1) جدول رقم (1)

Gov.	مقياس شدة الفقر Measure of the Poverty Acute P2			مقياس فجوة الفقر Measure of the Poverty Gap P1			نسبة الفقراء No. Of Poor People			المحافظة
	جمهورية Reb.	ريف Rural	حضر Urban	جمهورية Reb.	ريف Rural	حضر Urban	جمهورية Reb.	ريف Rural	حضر Urban	
Al-Maharh	0.66	0.2	1.12	1.8	0.81	2.78	8.85	6.29	11.4	المهره
Sana'a City	1.09	0	1.09	3.37	0	3.39	14.89	0	14.98	امانة العاصمة
Sa'adah	1.09	1.09	1.08	3.57	3.56	3.6	16.55	16.23	18.18	صعده
Aden	0.84	0	0.84	3.08	0	3.08	16.88	0	16.88	عدن
Dhamar	2.13	2.01	2.96	5.97	5.75	7.53	25.84	25.28	29.73	ذمار
Sana'a	2.29	2.29	0	7.02	7.02	0	28.13	28.13	0	صنعاء
Ibb	2.63	2.92	1.18	7.4	8.17	3.56	30.07	32.84	16.36	اب
Al-Mahweet	1.76	1.79	1.39	6.16	6.29	4.55	30.75	31.48	21.9	المحويت
Al-Hodeida	2.7	3.21	1.62	7.56	8.85	4.78	31.72	36.43	21.58	الحديده
Remah	2.68	2.75	1.24	7.96	8.19	2.58	34.07	35.32	5.38	ريمه
All Yemen	3.32	4.02	1.47	8.93	10.6	4.48	34.78	40.09	20.7	الجمهوريه
Hadramout	1.84	2.39	1.21	6.67	8.15	4.97	35.59	39.17	31.45	حضرموت
Taiz	3.64	4.08	1.96	9.8	10.96	5.41	37.8	41.51	23.66	تعز
Al-Dhale	2.59	2.61	2.43	8.71	8.99	6.57	44.24	46.37	28.15	الضالع
Abyan	5.11	5.73	3.23	12.94	14.52	8.17	45.68	50.44	31.37	ابين
Mareb	8.09	9.07	1.53	17.26	19.2	4.28	45.88	50.05	17.95	مارب
Laheg	5.75	6.16	1.36	13.82	14.7	4.53	47.2	49.49	22.9	لحج
Hajja	5.47	5.83	1.63	13.57	14.41	4.64	47.53	50.02	20.9	حجه
Al-Jawf	5.35	6.02	1.61	13.44	14.78	5.94	49.58	52.63	32.57	الجوف
Al-Baida	8.1	9.61	1.35	18.13	21.28	4.14	51.85	59.76	16.72	البيضاء
Shabwah	8.56	9.58	3.01	17.97	19.61	8.97	54.13	56.8	39.44	شبوه
Amran	5.62	6.13	3.34	16.24	17.82	9.17	63.93	70.6	33.93	عمران

*Source: HBS 2005-2006 *المصدر : مسح ميزانية الاسرة متعدد الاغراض 2005-2006