Using GIS and other Location Based Tools for the Registration, Design, Maintenance, and Mapping of Refugee Camps

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Abstract

The number of displaced people in the world is increasing at an alarming rate. Whether it is civil war, flooding, earthquakes or racial genocide, any number of world events could strip people of their homeland, forcing them to search for shelter and assistance. Overburdened by the growing numbers, humanitarian agencies are looking towards GIS and other technology to assist in relief efforts for refugees and internally displaced populations. Although location based tools such as GIS have been implemented in varying capacities, can they be fully utilized for the registration, design, maintenance, and mapping of refugee camps? The focus of this research paper involves the creation of GIS based applications customized to reduce the technical constraints encountered by camp personnel as well as incorporate components specifically developed for humanitarian aid operations. The applications contain numerous tools to facilitate data collection, camp registration and addressing, demographic analysis, camp infrastructure design validation, and the publication of easily distributable camp maps.

Introduction

From earthquakes and tsunamis to political persecution and civil war, each year natural and man-made catastrophes displace millions of people, leaving families searching for shelter or forcing them into ill-equipped refugee camps. Since the 2003 civil war or what many label as the genocide of Darfur, an estimated 4.4 million people in Sudan have been either internally displaced or become refugees (Vuni, 2008). The 2004 tsunami leveled villages in Indonesia leaving approximately half a million people homeless. The 2005 earthquake in Pakistan left over three million without shelter in the mountainous region of Azad Kashmir. Within the last year a reported 5,470,000 people were displaced after the 2008 earthquake in China (USAID, 2008).

Statistics such as these fill our newspapers and nightly news broadcasts, but it is important to remember that the problem of displaced people is ongoing. For example recent flooding in Myanmar has drawn world attention to the plight of millions left homeless and searching for food and shelter. Interestingly enough, prior to the flooding there were already 140,000 Myanmar political refugees living in nine border camps in Thailand, many of which have been there for up to twenty years (UNHCR, 2006).

It is also important to remember that even though these individuals share the common hardship of being uprooted from their home, they do not fit into one homogenous category. The United Nations

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High Commissioner for Refugees (UNHCR) classifies displaced people as "populations of concern" and further divides them into subcategories based on their situation and need. Groupings include refugees, internally displaced persons (IDPs), returnees, stateless persons, and asylum-seekers. Refugees are those who are currently living outside their country of residence and are unable to return because of persecution, war, or natural disasters. Internally displaced persons are those who have been forced to flee their homes due to man-made or natural disasters, but who have remained within the borders of their native country. Returnees are considered those displaced groups who return to their country of origin when situations permit. Stateless persons are those who are not considered a national of any state or country, while asylum seekers are those that have decided to obtain residence in foreign countries because of the political or environmental conditions that exist in their homeland.

The 2007 Global Trends publication from the UNHCR estimates that a total of 67 million people have been forcibly displaced, of which 16 million are considered refugees and 51 million IDPs. Of the IDPs, 26 million fled from their homes as a result of armed conflict and the remaining 25 million due to natural disasters. Nearly 14 million IDPs and 11.4 million refugees fall under the care of the UNHCR, which was created in 1950 by the UN General Assembly and charged with the responsibility of assisting governments with refugees (UNHCR, 2008a). Humanitarian aide that falls under the UNHCR's responsibility includes providing shelter, water, sanitation, and health care. It also involves the coordination and management of both individual camps and camp systems.

The number of refugees and IDPs falling under UNHCR care has been increasing over the past few years. Between 2005 and 2007 IDPs more then doubled from 6.6 million to 13.7 million. Refugee counts increased from 9.9 million in 2006 to 11.4 million in 2007 (UNHCR, 2008a). This increase has put a strain on the UNHCR and other organizations, which provide shelter and services to growing populations. Reports on the poor conditions of refugee camps including overcrowding, disease, violence, and resource shortages are widespread. An independent news organization describes the conditions of camps in eastern Chad as "waste-infested, tight living conditions" and explains the residents must "compete for water at the well and a limited number of latrines" (Dinka, 2007). In a press release from the United Nations (UN) regarding some 90,000 refugees in camps in southwestern Algeria, a joint assessment mission found that many residents lived in dire health conditions. The joint mission expressed the need for better food distribution, water handling, and hygiene (United Nations News Service, 2007).

On-line research of accounts and reports of refugee camp conditions identified a number of common problems which included: overcrowding, inefficient resource allocation, social and cultural issues, sanitation problems, violence, and inadequate infrastructure. Although no easy solutions to these problems were identified, the UNHCR and other organizations were utilizing technology to improve the settlement locations, streamline data collection, and improve camp designs.

GIS and Humanitarian Efforts

Geographic Information Systems (GIS) is one of the technologies currently being used by various United Nation organizations and humanitarian Non-Governmental Organizations (NGOs) to assist with humanitarian relief efforts. The UNHCR has a GIS/mapping unit, as well as the UN Joint Logistics Center (UNJLC), the UN Development Programme (UNDP), the UN Statistics Division (UNSD), and the UN Office for the Coordination of Humanitarian Affairs (OCHA). Not only does OCHA host web sites containing mapping resources, the organization also deploys Humanitarian Information Centers (UNHIC) which house small mapping units, situated near the natural catastrophe, conflict zone, or refugee camp.

These organizations utilize GIS, Global Positioning Systems (GPS), and satellite imagery for regional mapping, relocation efforts, resource allocation, and a number of other tasks associated with refugee efforts. Not only is it evident in published maps but also in refugee handbooks and manuals. A refugee camp management toolkit specifically states, "All mapping should be done with the Global Position System (GPS) and the Geographic Information System (GIS) technology" (Norwegian Refugee Council, 2004). The 2004 Practical Guide to The Systematic Use of Standards & Indicators in UNHCR Operations states, "the geographic dimension is vital for understanding refugee camp situations and making sound decisions. Geographic information can also be an extremely useful tool for surveys, in particular sampling methodologies." The guide also contains specific instructions for calculating camp space requirements and other spatial operations within a GIS (UNHCR, 2004b). The UNHCR Handbook for Emergencies sites GIS technology as a useful tool to calculate resource allocations, for site selection, and planning, as well as a common format for interagency data sharing (UNHCR, 2004a). In addition to the general camp mapping capabilities, many humanitarian agencies have identified GIS as a tool, which could improve the process of personal data collection. The Norwegian Refugee Council has concluded "GIS systems and GPS coordinates can be used to establish exactly where camp residents are living, their vulnerability, and area of origin, to mention a few advantages. This system could illustrate each household on a map of the camp and could include all necessary demographic information related to the family in question" (Norwegian Refugee Council, 2004).

GIS Limitations

Although the need for mapping and spatial analysis is undeniable, a comprehensive on-line search found few maps at the level of detail required for camp maintenance, but rather more closely related to a "push pin" regional view or what might be considered a macro-level cartographic product. Even more surprising was the lack of customized GIS refugee camp applications. Although there were articles describing joint efforts by various organizations only reference to one example was found. REMAPS (Relief Emergency Mapping System), a prototype extension for MapInfo, was briefly discussed and a video demonstration provided. After further investigation it was found that REMAPS was never completed due to lack of funding.

This lack of existing applications is further echoed by agencies and individuals involved with humanitarian efforts. An UNHCR Africa newsletter suggests the organization is faced with the challenge of developing standard GIS tools and methods for camp mapping (UNHCR, 2005). Commenting on using location-based information to manage refugee camps Luc St. Pierre suggested the UNHCR has a need for location based information solution to perform "spatial analysis for the efficient management of camps", but also explained "a simple GIS solution based on uniform models could not adequately provide the solution" (St. Pierre, 2008). Some of the reasons cited in the article as to why GIS could not adequately provide the solution included:

- Lack of trained GIS personnel
- Data issues including availability, adequacy, timeliness and relevancy
- Lack of access to high resolution satellite imagery because it is costly or unavailability in certain regions
- Addressing systems may not be in place or demographic data available at the camp level

The University of Cambridge's ShelterProject consists of a group of qualified individuals and organizations dedicated to improving the transitional settlement sector. This group has concluded, "Accurate and up-to-date GIS remains an under-used resource, despite its value for planning and co-ordination." Furthermore they feel that, "technical constraints and inadequate resources limit the current impact of GIS tools" (Corsellis and Vitale, 2005). In their opinion the GIS software is expensive and requires trained personnel to utilize it. Another important argument presented was "the systems used were not developed for humanitarian aid operations, and they have not been coordinated to integrate and analyze a series of information types common to aid operations" (Corsellis and Vitale).

Research Project

Working on the premise that GIS is under-utilized because of technical constraints and a lack of specific development for humanitarian aide, the focus of this research paper is to formulate an approach and develop prototype applications to address such issues. This will be accomplished by creating location based applications using GIS to possibly reduce some of the technical constraints encountered by camp personnel, as well as incorporate components which have specifically been developed for humanitarian aid operations. These components will:

- Be user friendly for non-GIS staff
- Include inexpensive or free software solutions
- Include intelligence and error trapping capabilities
- Incorporate spatial validation operations based on standard camp guidelines
- Enforce standard design practices
- Include flexibility
- Contain data capture methods based on existing camp forms or databases
- Include statistical operations and display of demographic data
- Include tools which simplify map production and web-based distribution

Methods

Strategy & Design

Refugee camps are extremely complex and ever changing communities, differing within each climate, culture, and country. To create a comprehensive tool set to handle every situation would be a daunting task and one that falls outside the intended scope of the research project. The purpose will be to illustrate how some important tasks common to camp administration can be automated and accessed through user-friendly applications utilizing GIS functionality. These tasks include registration data collection, demographic reporting, validation of camp design, and automated mapping capabilities.

The applications created to perform these tasks utilize ArcObjects within

ArcGIS ArcMap software, the Personal Spatial Database Engine (PSNL SDE) geodatabase stored within the free SQL Server 2005 Express Edition (SSE), and Visual Web Developer 2005 Express Edition (VWD), also free software.

As Figure 1 illustrates, front-end data entry web forms and report pages were constructed using ASP.Net within VWD. Connections between the web pages and SSE were created so that data could be written between the form and stored tables. SSE is also the storage environment for the PSNL SDE geodatabase, which not only contains the GIS feature classes but also enables ArcGIS with versioning, full replication, historical archiving, and other functionality reserved for the enterprise geodatabase. ArcMap applications, created using ArcObjects within the Visual Basic Application (VBA) environment, connect to the SSE in order to access tabular data created by the VWD forms as well as the stored feature classes. The attributes and geometry of these feature classes can then be exported to web maps through Keyhole Markup Language (KML) files consumed by Google Earth software.

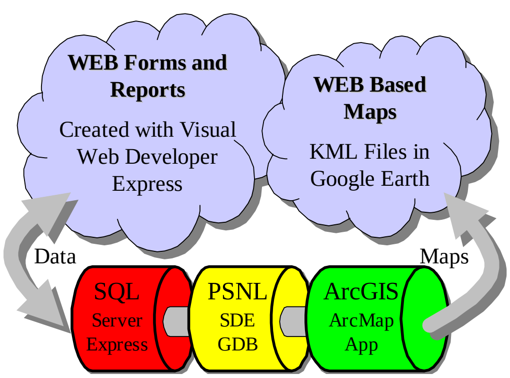

Figure 1. The research project, as illustrated in this conceptual design, is actually a combination of interconnected applications working together.

In the next few sections each application will be examined in more detail including explanations of the interconnectivity, evidence of the functionality, examples of the programming code, and illustrations of the customized application interface.

Data Collection

In order to create applications that would meet UNHCR specifications, information on refugee camp standards and design requirements were collected from such publications as Handbook For Emergencies, Camp Management Toolkit, and Practical Guide To The Systematic Use Of Standards & Indicators In UNHCR Operations. In order to create a test environment for the applications, the Forchana (or Farchana) refugee camp in eastern Chad, just 50 kilometers from the Sudanese border, was selected. Imagery was captured from Google Earth and rectified to a geographic coordinate system within ArcMap. The camp boundary was reproduced based on an image from United States Agency for International Development satellite imagery (USAID, 2004). Although not ground truthed, shelters and latrines sites feature classes were created using the imagery. Since the actual locations of these features as well as water taps, educational centers, medical centers, and administrative centers could not be verified, factitious locations were created for the sole purpose of testing the applications.

The Registration Procedure & Application

The refugee registration process is defined as "the recording, verifying, and updating of information on persons of concern to UNHCR with the aim of protecting and documenting them and of implementing durable solutions" (UNHCR, 2003). This process is essential for the successful creation, addressing, and management of any refugee camp. Family registration information can be collected through a number of procedures or tools including a hardcopy UNHCR “control sheet” form, as well as the automated Field-Based Registration System (FBARS) or ProGres, a new registration software program acquired by the UNHCR. Rather than attempting to acquire and incorporate either of these software packages into the research project, an alternative procedure was created. Given that the hardcopy control sheet form included in the UNHCR Handbook for Emergencies is a common tool for registration, it was used as the template for the registration application data entry form.

Since the goal of the research project was to create tools, which would increase user efficiency and accuracy by automating camp procedures, a fully functional web based registration form was created. The hardcopy control sheet form was replaced by a single ASP.NET web page created within VWD. Acting as the front-end data entry form, the page passes family information directly into the SSE database. Although a web-based front end was chosen, it is not dependent on an Internet connection and could be remotely deployed with SSE on any laptop running Internet Information Services (IIS) or even replaced with a pure VB.NET application.

The web control sheet shown in Figure 2 is a collection of text box and dropdown list controls organized to efficiently and accurately capture data required for registration. The dropdown lists contain manually entered choices or field values found in SSE tables. Database tables can be bound to a VWD control by using the SqlDataSource control, which allows the user to access individual field values in a relational database table by opening a server connection and executing an SQL statement. For example the distinct country values available in the country drop down list control were generated from the administration feature class attribute table stored in the PSNL SDE geodatabase within the SSE relational database management system. Once a country is selected, a list of administration districts within each country is populated into the location drop down list.

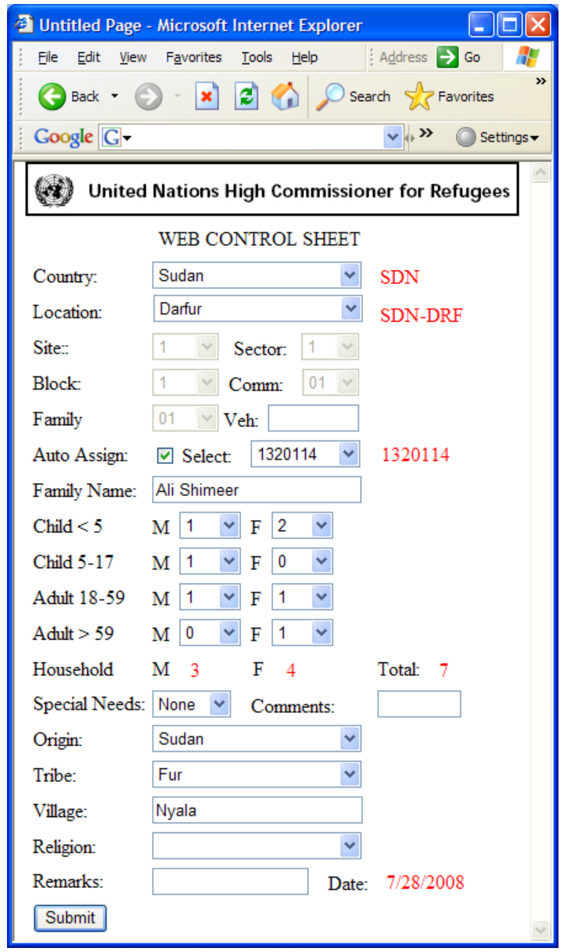

Figure 2. A control sheet registration form was recreated in a single web page using VWD.

The generation of the administrative district list for the chosen country is possible because the location control is also bound to the same feature class table but the country dropdown list control executes a filtered query returning only those values that satisfy the SQL statement shown below.

Select [ADMIN_NAME] From [ADMIN] Where ([CNTRY_NAME] = @CNTRY_NAME) Order By [ADMIN_NAME]

By retaining the country name in the variable @CNTRY_NAME, a sub query statement can be made to return only those administrative districts within the selected country, as shown in Figure 3. For more information on the tables associated with the web form refer to Appendix A.

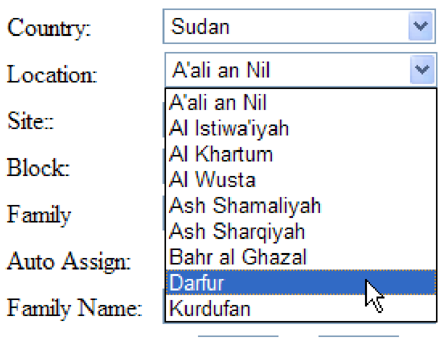

Figure 3. Table values are bound to dropdown list controls, which promote data integrity by providing only legitimate choices.

Assuming that an addressing system has been set up, family data is linked to a camp address by a unique address identifier or chosen from an existing site list. A unique address number could be generated by aggregating values from the site, sector, block, community, and family dropdown lists, which correspond to camp divisions as prescribed by the UNHCR. Otherwise the auto-assign option is available if a point shelter feature class exists and contains information on the occupancy. The application connects to SSE, which also houses the shelter points in a PSNL SDE geodatabase format. Address numbers from the shelter feature class with an occupied attribute field containing “N” for not assigned or available, are displayed in the dropdown list. After the user selects an address number for assignment to a family, code is initialized to remove it from the available shelter list by changing the occupied field value to “Y.” As the following code illustrates, the SQL statement held as a variable, is passed to SSE and executed, which in turn updates a record.

```
sqlstring2 = "UPDATE dbo.SHELTER Set
OCCUPIED = 'Y' Where PLOT_NUM = '" &
joinitem & "'"
Dim sqlCmd1 As New SqlCommand(sqlstring2,
sqlConnection)
sqlConnection.Open()
Try
  sqlCmd1.ExecuteNonQuery()
  Catch ex As Exception
End Try
sqlConnection.Close()
```

Information on the family name, age groups, gender, country of origin, religion, village, and special needs are collected with the remainder of the dropdown list and text box controls. Logically the next step would be to formulate an INSERT SQL statement and send it to SSE using code similar to the previous example. However it is important to check for SQL injection attacks prior to sending this or the previous UPDATE statement to the database server. SQL injection attacks can be described as attempts to insert malicious code into strings passed to SSE. This code could initiate a security breach of the database or application. One way to guard against this is to use parameterized queries, which are embedded parameters within the SQL query statement. Another option is to cleanse the string values held in variables by using a function to check for harmful commands, query delimiters, or possible stored procedures. The latter option was incorporated into the application as illustrated in the next code example. The killInjection function searches for user-input variables that are concatenated with SQL commands. If found it strips it out by replacing them with nothing (“”).

```
Dim joinitem As String
joinitem = Trim(killInjection(LabelShelter.Text))
Dim vehText As String
vehText = Trim(killInjection(TextVehicle.Text))
```

```
Dim refName As String
refName =
Trim(killInjection(TextBox_Name1.Text))

Function killInjection(ByVal strWords)
Dim injectionChars() As String = {"'", "select",
"drop", "update", ";", "--", "insert", "delete", "xp_"}

Dim newChars
Dim i As Integer
  newChars = strWords

  For i = 0 To UBound(injectionChars)
          newChars = Replace(newChars,
          injectionChars(i), "")
  Next
killInjection = newChars
End Function
```

Once the user is finished entering in the demographic data and clicks on the submit button, error checking takes place and the killInjection function initialized on the specified controls. An SQL statement is then constructed and sent to SSE using the ExecuteNonQuery method of the SQLCommand class. This method executes the INSERT transact-SQL statement against a current SQL connection, which adds another record to the existing control sheet table. Updates to this table are instantly reflected and accessible by other applications including ArcMap and web-based demographic report tables.

Demographic Data & Application

When designing a refugee camp it is important to respect and respond to the needs of various demographic groups. By assessing the age, tribal customs, religion, and vulnerability of the residents, better decisions can be made regarding the camp infrastructure, services, and resource allocation. As stated in a document by the ShelterProject, "the resulting profile of the displaced population will describe how the displaced population should be living, socially and economically. This profile will help aid organizations to prioritize the needs of the displaced population within the sites of future camps" (Corsellis and Vitale, 2005).

The refugee family data collected from the web application provides camp managers with essential demographic information on the residents including predominate age groups, vulnerabilities, family size, and cultural groups. In order to display and assess this data, a second application was written. Using ArcObjects in the VBA environment, a four-tab form was created for use within ArcMap. Figure 4 shows the first tab of the application, which displays demographic statistics on age, vulnerability, and cultural traits.

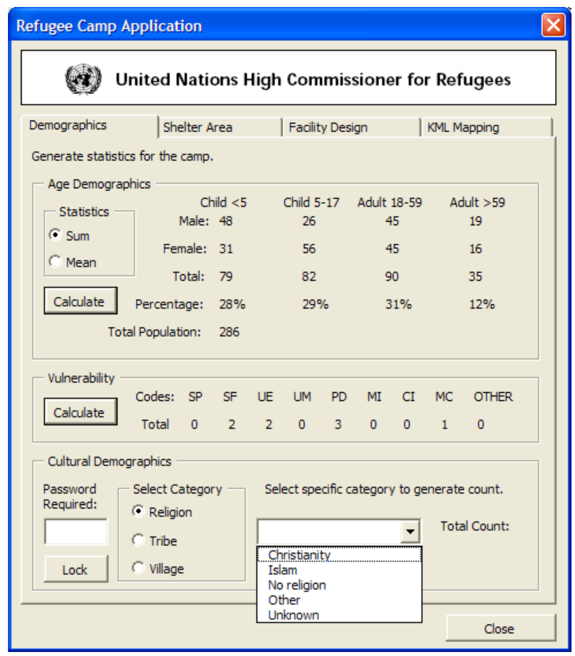

Figure 4. The first tab of the ArcMap application displays demographic data collected from the control sheet.

The age demographics are subdivided into the same range categories organized on the control sheet, displaying the total counts, percentage, and statistical mean of male and female camp residents. The vulnerability section displays total counts per coded vulnerability category. The third section is cultural demographics, which is usually not captured when filling out the control sheet. However, publications such as the Camp Management Toolkit recommend collection of additional information on ethnicity, religion, and country of origin as long as confidentiality is respected (Norwegian Refugee Council, 2004). Thus access to the information in this section is password protected. Once unlocked, the application displays counts on the various religious groups, tribes, and village members present in the camp.

In order to display the current statistics from the camp database the user clicks the form calculate button. This initiates a connection to the SSE table populated by the control sheet. Once the connection is made, much of the statistical information is generated using the ArcObjects DataStatistics class accessed through the IDataStatistics interface. This class provides access to members that generated statistics on the desired fields. For example, the code shown below will create an object that holds the CHILD_5_M field, and is referenced to the control sheet table object variable newTable. A cursor is used to traverse the table and gather the results from that field. An object created from the StatisticsResults class is used to hold that information. Once completed, the label on the application window will then display either the sum or mean statistics depending on whether the sum control (OptionCount) or the mean control (OptionMean) was selected by the user.

```
Dim pData As IDataStatistics
Set pData = New DataStatistics
pData.Field = "CHILD_5_M"

Dim qCursor As ICursor
Set qCursor = newTable.Search(Nothing, False)
Set pData.Cursor = qCursor

Dim result As IStatisticsResults
Set result = pData.Statistics
Dim pCHILD_5_M As Integer
If OptionCount.Value = True Then
  c5m.Caption = result.Sum
  pCHILD_5_M = result.Sum
ElseIf OptionMean.Value = True Then
  c5m.Caption = Round(result.Mean, 1)
  pCHILD_5_M = Round(result.Mean, 1)
End If
```

The vulnerability category counts were generated using a slightly different method. A query filter was built using the IQueryfilter interface and nested within a loop of possible vulnerability codes stored in an array. The records for each code were queried, totaled, and then displayed on the form.

The code behind the cultural demographics section also uses query filters and the various statistics interfaces previously mentioned. However it does it in a somewhat different fashion. First the user selects the religion, tribe, or village category. Once this is completed the application generates a unique list of values and display them in the drop down box. This is accomplished by using the SQL DISTINCT function as shown below.

```
Dim pQF As IQueryFilter
Set pQF = New QueryFilter
pQF.SubFields = "DISTINCT(RELIGION)"
Dim pCur As ICursor
Set pCur = newTable.Search(pQF, False)
Dim pRow As IRow
Set pRow = pCur.NextRow
```

A cursor is initiated to loop through the control sheet table and organize a list of all the distinct religious groups. Each group is added to the dropdown list as previously illustrated in Figure 4. Once a distinct group has been selected a query filter is built and statistics run on that subset using the IDataStatistics interface similar to the previous example.

The demographic statistics displayed on the customized ArcMap form provide useful information. However since the population totals displayed are static labels displaying demographic data within a VBA form, full utilization of the statistics is limited. In other words, it cannot be transferred to a report or document. To add more flexibility and illustrate how easy it is to generate demographic tables, the ArcMap map document includes a customized menu with additional reporting options. These report options include:

- Population Per Sector/Block
- Country of Origin Per Sector
- Male Population Per Sector
- Female Population Per Sector

Selecting a report option will display a tabular report organized on a web page as shown with two examples in Figure 5. The pages were created in VWD and have a GridView control bound to the SSE control sheet table. Upon initialization of the web page a server connection is made and SQL statement sent, which returns the current demographic data in a readable table format.

United Nations High Commissioner for Refugees

Camp Male Population Per Sector

SECTOR NUMBER	BLOCK NUMBER	MALE TOTAL
1	1	19
2	1	25
3	2	43

United Nations High Commissioner for Refugees

Camp Origin Population Per Sector

SECTOR NUMBER	COUNTRY OF ORIGIN	HOUSEHOLD TOTAL
1	SDN	46
2	SDN	39
2	TCD	10
3	SDN	80

Figure 5. These examples illustrate how easy it is to generate demographic tables with VWD and SSE.

Camp Design & Application

The basic necessities offered in a refugee camp are food, water, sanitation services, health facilities, and shelter. Although the type of shelter may vary by location or available resources, there are underlying principles regarding infrastructure placement and density, which are common to most. Placement of shelters and their proximity to other structures may have a direct affect on the success of a camp. Evidence that the camp's overall design and the distribution of shelters has a positive influence on the residents is found in the 2004 UNHCR Handbook for Emergencies, where it states that good planning and shelters will:

1. Save lives and reduce cost
2. Minimize the need for difficult corrective measures
3. Make the provision of utilities, services, and infrastructure easier and more cost-effective
4. Ensure most efficient use of land, resources, and time

Good shelter planning can also improve the health and welfare of the residents. Adequate or minimum living space standards are considered preventative measures for disease control of measles, tuberculosis, and typhoid (UNHCR, 2004a). Overcrowding due to poor planning is one of the key contributors in the transmission of diseases, as well as promoting civil unrest, safety concerns, inadequate resources distribution, and lack of privacy.

When assessing shelter area design and resident overcrowding, the two important factors are population and camp size. Dividing the camp size by the population produces a surface area per person ratio. Although the recommended minimum surface area may differ between relief organizations, most recognize 30 square meters (m^2) per person as the required minimum. The amount of 30 m^2

factors in area for roads, paths, sanitation, educational and health faculties, resource storage, common camp buildings, and of course the family shelter plots. This area is increased to 45 m² to account for personal gardening or camp agricultural land requirements (UNHCR, 2004a).

The second tab in the ArcMap application (Figure 6) is a personal surface area calculator. The basic surface area calculation is performed using the camp boundary polygon and a current population count from the SSE control sheet table. Surface area calculations can also be generated with a population estimate or an estimate for a sub-section of the camp. In addition the user can override the default 45 m² UNHCR standard in cases of an emergency situation or where gardening and agriculture will not be factored in.

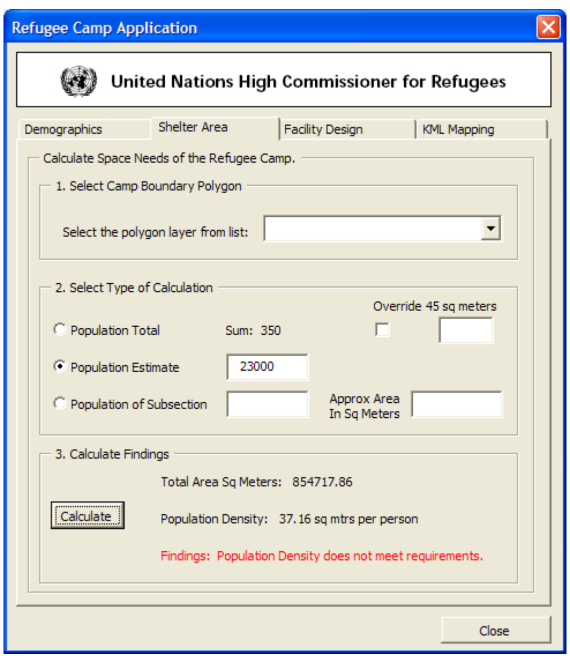

Figure 6. A warning message will display if the surface area per person ratio does not meet UNHCR recommendations.

Camp Facility Validation & Application

Shelters are just one component of a refugee camp whose spatial proximity can be captured, analyzed, and even modified in order to improve the quality of life for the residents. The location of other structures such as water taps, latrines, health facilities, waste bins, and lighting structures also warrant consideration. The spatial distribution of these components could have a direct affect on resource allocation, facility maintenance, service delivery, and ultimately the quality of life in a camp. Latrines in close proximity to water sources could increase the possibility of water contamination and the spread of typhoid or hepatitis. The location of resident shelters to water sources or latrines could be considered a security issue especially for unescorted women and children forced to walk long distances.

After reviewing available literature, recommendations for facility design and infrastructure layout were collected from the SphereProject (SphereProject, 2004), the UNHCR (UNHCR, 2004a) and the Norwegian Refugee Council (Norwegian Refugee Council, 2004). Data pertaining to optimal facility distances as well as resident to facility ratios were gathered for a number of camp facilities and organized in a tabular format as illustrated in Table 1.

Table 1. Camp design recommendations, which could be spatially validated, were organized into tables.

Design Consideration	Distance	Agency
Shelter to Water (Max Distance)	500	Sphere
Shelter to Water (Max Distance)	100	UNHCR
Shelter to Water (Max Distance)	150	NRC
Water to Latrine (Min Distance)	30	Sphere
Water to Latrine (Min Distance)	30	UNHCR
Water to Latrine (Min Distance)	30	NRC
Shelter To Latrine (Min/Max)	30/50	Sphere
Shelter To Latrine (Min/Max)	30/100	UNHCR
Shelter To Latrine (Min/Max)	30/100	NRC

The third tab of the ArcMap application (Figure 7) is a facility design tool, which provides an easy way to validate distance recommendations between facilities. Although spatial validation could be performed on a number of camp components, for this application three examples were chosen; shelters, water taps, and latrines. As Table 1 illustrates, agencies may differ on suggested distances, so the first task for the user is to choose which agency recommendations will be used for the analysis. The user also has the flexibility to override any recommendations and input a desired distance as illustrated in Figure 7. Once the validation button is selected a count of non-compliant facilities is displayed in red text. Since resident to facility ratio is also important, an example of the number of people per water tap can also be generated. Population per tap is based on an assumption that residents would obtain water from the nearest (shortest travel distance) tap. However due to social circles, physical barriers, and other factors this may not always be the case.

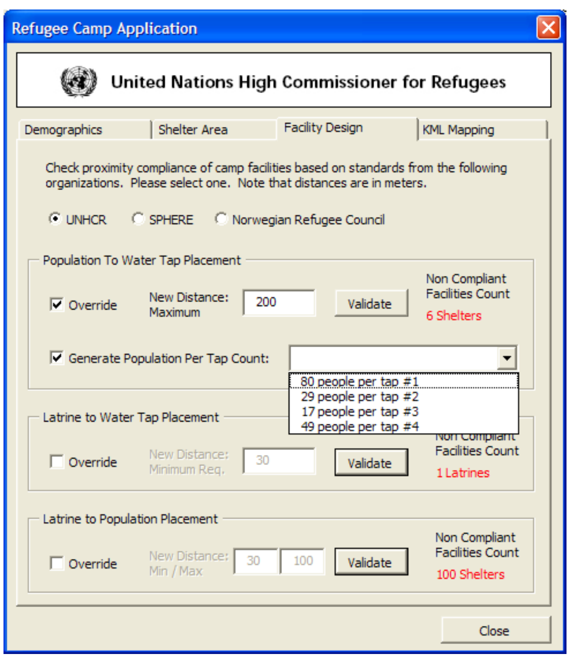

Figure 7. The facility design tool can validate distances and return the number of non-compliant facilities.

The spatial validation process is accomplished by using two different techniques. The first method was created based on code snippets found on an ESRI support page and is similar to performing a spatial join. The validation button initiates the creation of a spatial index using the IFeatureIndex interface. It stores information in memory on the proximity of all features from the "searchable" layer to one single feature within the "original" layer. The nearest feature found within the searchable layer is determined by using the IndexQuery class with the NearestFeature method. The stored feature index is queried and the nearest feature to the single feature of the "original" layer is returned with the distance calculation. In the case of the population (original layer) to water tap (searchable layer), the code loops through shelter locations one feature at a time, building a spatial index and determining the closest water tap to the single shelter. The distance and tap ID are captured and stored in the shelter feature class along with a code designating if the shelter is outside or non-compliant with the allowed distance as shown in Table 2.

Table 2. After running a shelter to water tap distance validation, the shelter feature class is attributed with actual distance to water tap, the water tap number, and a compliance code.

DISTANCE	TAP_ID	COMPLY_TAP
46.78036	1	GOOD
168.795067	1	OUTSIDE
160.395383	1	OUTSIDE
157.41806	1	OUTSIDE
171.798483	1	OUTSIDE
191.10483	2	OUTSIDE
172.75066	2	OUTSIDE

Within the map document, the shelter feature class is joined to the SSE control sheet table. If the user checks the Generate Population Per Tap Count checkbox, a total population per tap can be generated because shelter feature class contains both the nearest tap ID (TAP_ID) as well as the total number of individuals in each shelter (HOUSEH_TOTAL). A query filter is created based on TAP_ID and statistics run using the DataStatistics class on the joined HOUSEH_TOTAL field in a similar manner as previously explained.

The latrine to water tap and latrine to population placement functions calculate distances using a method that takes advantage of the GpDispatch object to gain access into the geoprocessing tools. The existing Select Layer By Location (Data Management) geoprocessing tool is accessed from ArcMap and used to select latrines within a specific distance. As shown in the code snippet below, the tool is given the parameters of the base feature class, the type of selection, the selectable feature class, the distance, and the new selection option.

```
GP.SelectLayerByLocation_management
pFeatLayer2, "WITHIN_A_DISTANCE",
pFeatLayer1, maxLat, "NEW_SELECTION"
```

Since the shelter to latrine validation actually has both a minimum and maximum distance requirement, the process is two fold. The application selects all shelters within the specified maximum distance and codes them as "GOOD," then does a switch selection operation and calculates all other features as "OUTSIDE." The application then runs another select by location operation with the minimum distance and calculates all shelters returned to "INSIDE" or what might be considered too close to the communal latrines. As Figure 8 illustrates, once this process is complete each shelter can be symbolized to illustrate if the current location is within both the recommended minimum and maximum distances set down by the chosen agency. Generating maps from this information will help camp administrators decide on the most suitable locations for new communal latrines as well as where to plan and construct new shelter sites.

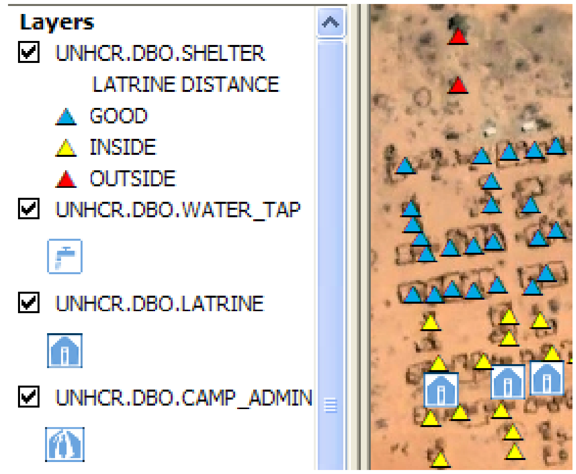

Figure 8. The shelter feature class has been symbolized to illustrate compliance with minimum and maximum distance recommendations to latrines.

Refugee Camp Mapping & Application

Mapping is an extremely important function for the design and management of the refugee camps. It is considered a standard activity during site selection with a focus on accessibility, topography, water availability, underlying soils, and safety aspects. As stated in an article on mapping camps in the Gaza Strip, "the UN involvement in mapping for the developing world will increase, and mapping will become increasingly important for the management of refugee situations" (Kavanagh and Home, 1999). On April 8th, 2008 the UNHCR announced they would be working with Google to provide "a powerful new online mapping program that provides an up-close and multifaceted view of some of the world's major displacement crises and the humanitarian efforts aimed at helping the victims." The press release explains that the Google Earth Program will allow various organizations to share geographic information and efforts as well as create useful data for logistics planning (UNHCR, 2008b).

The final tab of the ArcMap application (Figure 9) is a Keyhole Markup

Language (KML) mapping utility similar, but scaled down from the application mentioned in the UNHCR's press release. KML is an XML-based language schema for location and display of geographic information in both two-dimensional and three-dimensional environments within Google Earth browsers. It uses a tag-based structure to hold elements and attributes of the various geographic features. The custom mapping application populates these tags with location and attribute information directly from the selected GIS layers into a KML formatted text file. The actual syntax used in the text file was based on the XML structure found in the downloadable UNHCR_Google_Project.kml example file linked to the web article (UNHCR, 2008b).

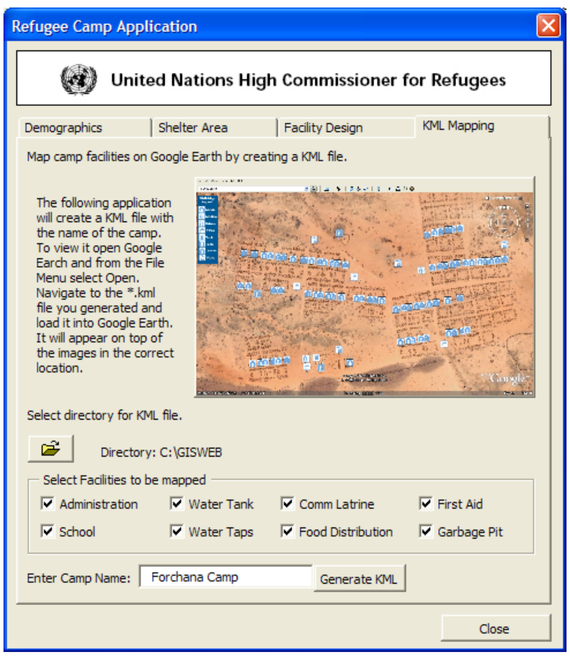

Figure 9. The final tab of the application is the KML mapping utility.

KML files can georeference points, lines, and polygons features, however in this application it is limited to points only. Within KML documents individual point features are considered "placemarks" and include a point element, which stores the geographic coordinates in decimal degrees. They may also contain tags referencing a style group as shown below, which stipulates how the point will be drawn. Placemarks could also contain text within HTML tags to display feature information within a popup balloon format. The CDATA reference below indicates that text within the brackets should be treated as unparsed character data and not XML, which will display it in a popup text bubble.

```
<Style id="style_latrine">
<IconStyle>
<scale>.8</scale>
<Icon>
<href>http://localhost/GIS_Demo/Images/latrine.png
</href>
</Icon>
<hotSpot x="20" y="2" xunits="pixels"
yunits="pixels"/>
</IconStyle>
</Style>
<Placemark>
<styleUrl>#style_latrine</styleUrl>
<description>
<![CDATA[
<p>Building Type: Latrine</p>
<p>Camp Name: Forchana Camp</p>
<p>Map Created By: Jay Meehl</p>
<p>Published On: 6/29/2008</p>
]]>
</description>
<Point>
<coordinates>21.79113995,13.59905271,0
</coordinates>
</Point></Placemark>
```

The ArcObjects code written for this application creates a text file based on the specified directory and camp name. The VBA Open and Print functions are used to enter text strings into the file. A standard header is written followed by tags for style groups, which reference PNG (portable network graphics) files to symbolize the features. Three PNG graphics files were copied from the existing UNHCR application while the remaining symbols were made by hand in PaintShop Pro. The application then loops through the desired GIS layers (checked in the form) and calls a sub routine with layer specific parameters as illustrated below.

```
If CheckLatrine.Value = True Then
  pStyle = "style_latrine"
  Call CreateKMLPoint(sTextFileName,
"UNHCR.DBO.LATRINE", pCampName, pStyle,
"Latrine")
End If
```

A FeatureCursor class object is then used to loop through the point feature class and write specific KML elements, along with the XY coordinates (newLong & newLat variables) for each point feature, to the text file as shown below.

```
Print #1, "<Placemark>"
Print #1, "<styleUrl>#" & pStyle & "</styleUrl>"
Print #1, "<description>"
Print #1, "<![CDATA["
Print #1, "<p>Building Type: " & pBuilding &
"</p>"
Print #1, "<p>Camp Name: " & pCampName &
"</p>"
Print #1, "<p>Map Created By: Jay Meehl</p>"
Print #1, "<p>Published On: " & Date & "</p>"
Print #1, "]]>"
Print #1, "</description>"
Print #1, "<Point>"
Print #1, "<coordinates>" & newLong & "," &
newLat & ",0</coordinates>"
Print #1, "</Point>"
Print #1, "</Placemark>"
```

The final product is a KML file utilized within Google Earth to overlay camp facilities, attribute information in text bubbles, and a stationary legend, over the imagery. See the example in Appendix B.

Results

Under normal circumstances an application would undergo thorough internal testing followed by implementation and assessment in real world scenarios. Since this was not possible each application component was run through a number of internal tests followed by a mock scenario involving the Forchana refugee camp. Tests were first conducted on the web control sheet, which was used to capture fabricated demographic data on 55 imaginary families and assign them existing shelters. The web form was checked for correct display, error catching, performance, and initialization of .NET routines. Data entry was monitored in the SSE table to make sure that correct values were written to the appropriate fields within the control sheet table. During the initial testing phase of the registration form a couple of issues were uncovered as described below.

1. *Excessive web page refreshing.* This is produced when web controls have auto-postback enabled, which forces a call to the server to perform an operation rather then handling them on the client side. The return message or information initiates a web page refresh. Future versions would have to incorporate more client side functionality.
2. *Duplicate auto assigned addresses.* Unique shelter numbers displayed in the auto assign option of the web control sheet are not removed until the final form submittal. Opening additional pages would display the same shelter availability list, which could create addressing conflicts. Change in shelter occupation attributes would need to be initiated upon selection change of that control and not after submittal.
3. *The entry form is not set up for multiple special needs categories per family.* A family could have both a missing child and a single female parent or any number of other combinations. Future versions would have to include additional tables to accommodate multiple special need listings.

4. *Country selection possibilities.* Additional improvements could be made to reduce the country, location, and origin country selections based on continent.
5. *Data entry limitations.* Once an entry has been made any modifications to that record would need to be completed within the feature class or SSE table directly. A web form would need to be created for search and modification of family records.
6. *Editing and updating a geodatabase outside of an ArcMap session.* The VWD application writes records to the table and creates the OBJECTID by using an SQL IDENTITY function. There is a possibility that if editing takes place directly within SSE unique numbering of the OBJECTID may get out of synchronization with the tables internal ID. More testing is required to understand and correct this issue.

The demographic data created during the initial tests and stored in the SSE database was joined to the shelter point feature class so that the ArcMap applications could subsequently be tested. The procedure was fairly simple; set parameters, initialize or validate the form, record, compare the statistics, and repeat. If the findings remained consistent then either parameters or shelter locations were changed and the tests rerun. During this process age group totals were compared to SQL queries run on the control sheet table to ensure accurate display. Comparisons were made concurrently with web control sheet entries to make sure that only current statistics were shown. Vulnerability and cultural information were also compared with the table totals. Shelter area validation was run against both the fabricated population totals and manually entered estimates and camp subsection areas. After testing the first two tabs of the ArcMap form the only issue requiring correction involved rounding errors on a couple of numeric displays.

A number of different scenarios were run against the forms facility design tab. Feature classes were symbolized based on various attribute information and visually checked after each change in parameter or shelter location. For example, after the population to water tap validation was run, the shelters were symbolized based on the water tap identification number (TAP_ID) and reviewed to determine if the correct tap number had been assigned as shown in Figure 10.

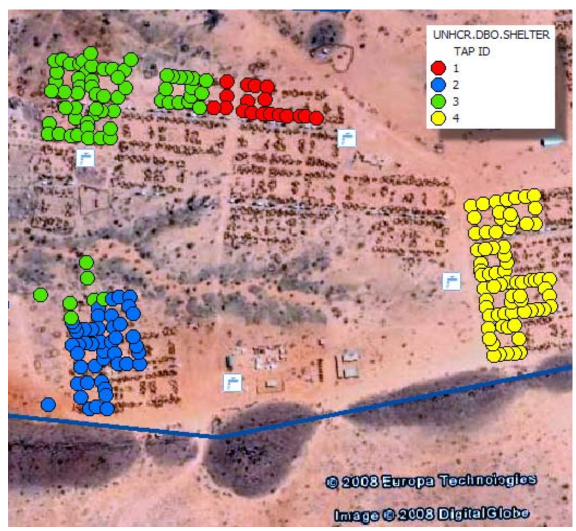

Figure 10. By symbolizing shelters based on nearest water tap IDs, attribute values were visually checked and verified within ArcMap, as this modified screen capture illustrates.

The shelters were then symbolized based on an attribute field that was coded with a “GOOD” if within the acceptable distance or “OUTSIDE” if they lie beyond the recommended distance, which for this example was 150 meters. Buffers were created in ArcMap to verify the findings as shown in Figure 11.

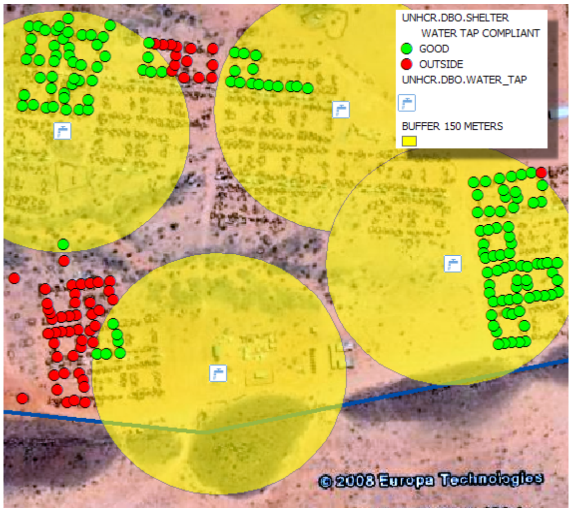

Figure 11. Buffers were used to verify which shelters were outside the recommended distance to the water taps, as shown in this modified ArcMap screen capture.

Latrine to shelter distance was validated based on a 30-meter minimum and 100-meter maximum recommendation. Shelters were symbolized in yellow for inside, red for outside, and blue for compliant shelter distances. Random measurements, illustrated in Figure 12, were taken between shelter and latrine to verify the application correctly calculated the distance and populated the attributes.

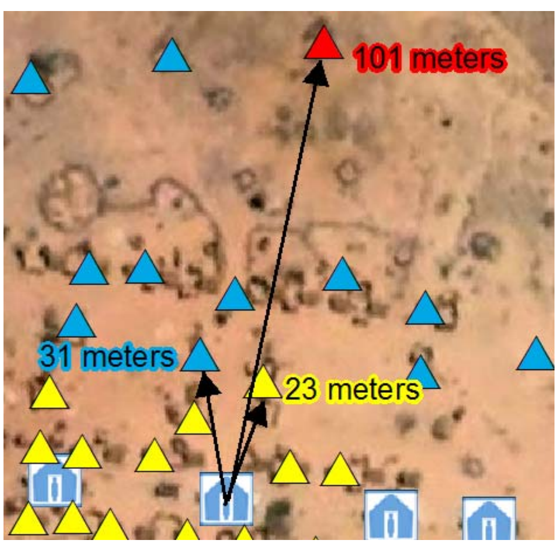

Figure 12. During the testing process shelter to latrine distances were randomly checked in ArcMap.

A number of additional tests were run on the mapping portion of the application as well as interconnectivity between the web control sheet and ArcMap applications. One of the biggest problems encountered was the number of connection instances. SQL Server Express was used so that both the applications and their users could take advantage of a free, full functional relational database management systems with full security capabilities, interoperability, administrative tools, backup utilities, and transact-SQL (structured query language) for communicating with the databases. Furthermore feature classes were stored in PSNL SDE geodatabases instead of File or Personal geodatabases because this would give the user the ability to perform replication, historical archiving, and a number of other functions reserved for enterprise geodatabase users. The only problem is that PSNL SDE geodatabases within SSE only allow four connection instances. Should a fifth connection be attempted the user would receive a "failed to connect to database, number of connections of instance exceeded." Further testing would need to be performed and alternatives such as the personal geodatabase, which stores datasets within a Microsoft Access data file, examined for feasibility.

Summary

This research paper has provided evidence that user-friendly applications, customized to perform some of the camp asset management operations, could be created using GIS in conjunction with other free or inexpensive software packages. In regards to refugee camp registration, design, maintenance, and mapping, these applications provided the user with tools to perform the following tasks:

1. Data collection in an efficient and

accurate manner, while providing "real time" access from other applications.
2. Camp addressing by connecting the registration information to specific shelter locations.
3. Report generation by displaying demographic information in tabular format web pages and application forms.
4. Spatial validation by identifying facilities that do not adhere to humanitarian agency distance recommendations.
5. Population per facility ratios by determining resident counts per facility.
6. Surface area calculation by evaluating whether residents were given recommended living space.
7. Camp mapping through the creation of KML files, which can display facilities over Google Earth satellite imagery and be shared between humanitarian agencies.

There would still need to be further development, testing, possible modification, and packaging before the following applications could be used in real world situations. This paper has illustrated how technology could be customized and incorporated into humanitarian efforts, which in turn, could directly or indirectly improve the quality of life for those without a home.

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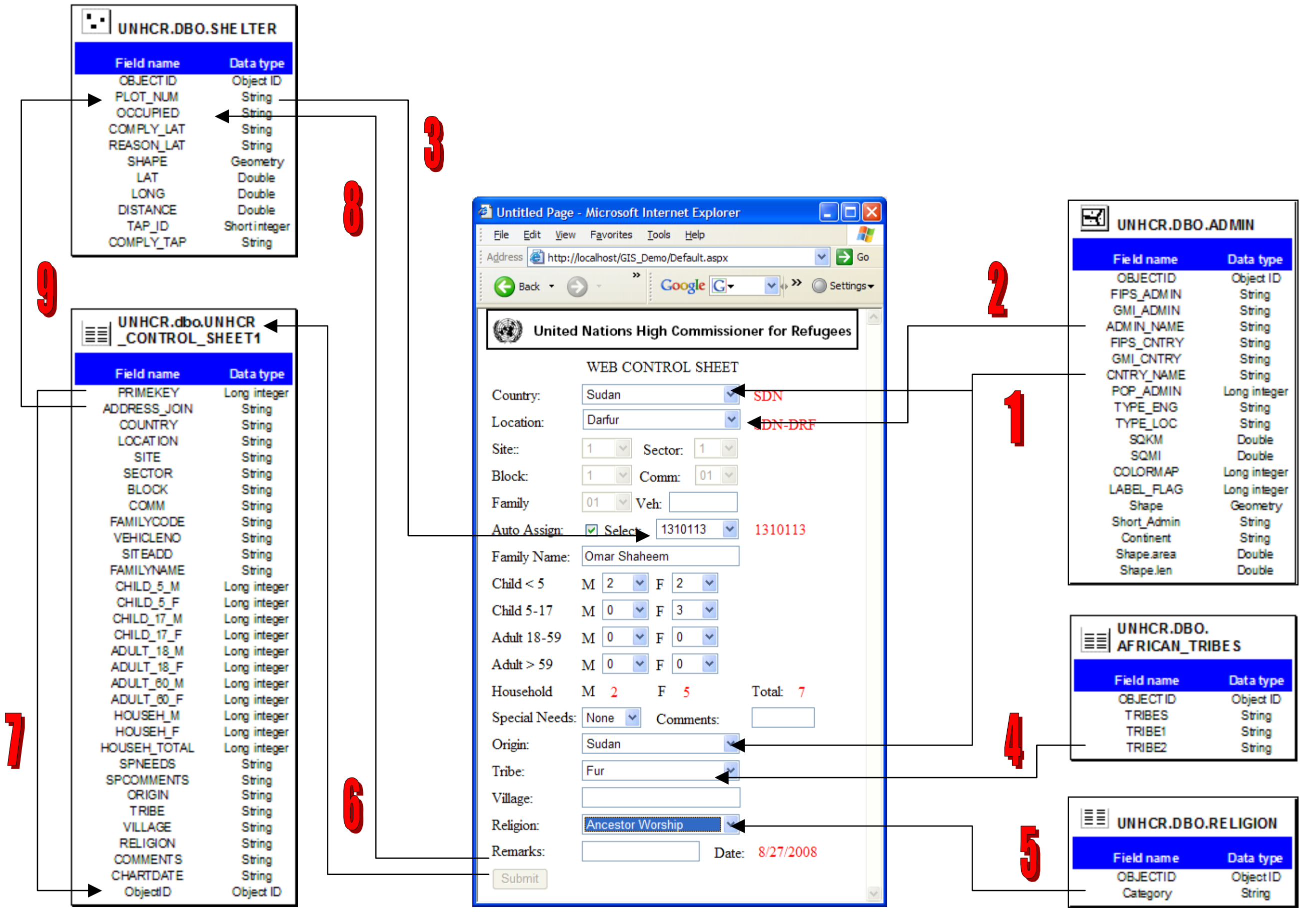
Appendix A. The following diagram illustrates the database design for the web control sheet.



1. Country names from the ADMIN table populate the dropdown country list.

2. The selected country is used in a SQL statement to return administrative districts from the ADMIN table.

3. Shelters with an OCCUPIED code of "N" are bound to the site number dropdown list.

4. Country names from the ADMIN table are bound to the Origin dropdown list.

5. Values from the RELIGION table are displayed in the religion dropdown list.

6. Information from the web control sheet is written to the UNHCR_CONTROL_SHEET1 table using the INSERT SQL statement.

7. The PRIMEKEY field value is copied to the feature table ObjectID.

8. The OCCUPIED field in the SHELTER table is calculated with a "Y" if the auto assigned number was used.

9. The UNHCR_CONTROL_SHEET1 table and SHELTER table are joined.

Appendix B. The KML map example, displayed in Google Earth, was created with the ArcMap application. Hovering over a camp facility will display attribute information in a text balloon.