**Address Numbering System for the City of Khartoum, Sudan**

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## Abstract

In the last ten years the city of Khartoum has experienced extremely rapid growth. This growth has created a high demand for a user-friendly infrastructure which allows people to find a specific location. This paper explores solutions GIS can provide to solve the missing address problem which exists in Khartoum, the largest city in Sudan. Additionally, the project establishes a framework for a uniform system which assigns numbers to dwellings, buildings, and businesses for the city of Khartoum to facilitate emergency services, deliveries, and to provide advantages of a uniform addressing system. A customized tool was created in ArcObjects to allow the user to find an exact address by calculating the XY of the desired location within the boundaries of Khartoum.

## Introduction

"A historian of urbanism once described cities as cultural complexes that seem to have sprung up on the banks of a few great rivers. The nucleus of such settlements must have appeared long before the city had come to full maturity. Khartoum seems to conform to this principle. For at a much earlier date before its development into a large urban conglomerate in modern times, a Mesolithic (i.e. Middle Stone Age) flourished on the left bank of the Blue Nile"(Alsunut Development). Khartoum was founded in 1823 by Ali Basha, the Egyptian ruler, and Omdurman was founded in 1884 by Mohammed Ahmed, the "Mahdi." At that time it was just a small rural village but the Mahdi used it as a base to launch his successful attack on the British in the city of Khartoum. It later became his capital. Khartoum lies along the left bank of the Blue Nile, and forms a huge triangle (Figure 1).

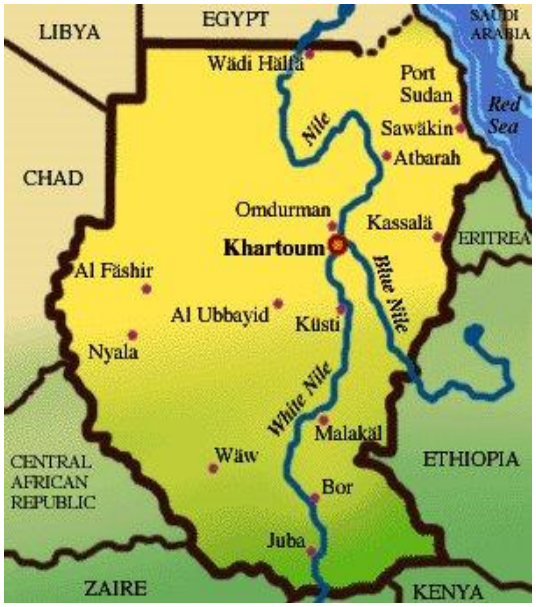

Figure 1. Sudan Map.

Its vertex is at the confluence of the two Niles – the White Nile on its western side, the Blue Nile to its east, and the base bordering Gezira State 30 kilometers southward. It is situated on latitude 15°36N, and longitude 32°32 E,

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and it is 1352 ft above sea level. Its population has grown to over 5 million people. Khartoum, together with the two cities, Omdurman and Khartoum North (Bahri) are jointly called the tri-capital, and constitute the National Capital of the republic of Sudan, the most urban city in the country.

Addresses are the location identifiers most widely used by the public and by state and local government. Addresses are critical information for administrative, emergency response, research, marketing, mapping, GIS, routing and navigation, and many other purposes. Because various addresses have evolved over many decades under the control of thousands of local jurisdictions and in many different record and database formats, different address formats and types pose a number of complex geoprocessing and modeling issues. As a consequence, government agencies struggle with these issues as they seek to integrate large, mission-critical files into master address repositories. In many places addresses are also used to identify infrastructure facilities, including bus stops, fire hydrants, utility poles and meters, cell phone towers, manholes, and signs (Federal Geographic Data Committee, 2010).

In Khartoum, except in very rare cases, street names or building numbers are not indicated. There is no systematic method of naming smaller streets, and it is not always apparent when or why they were assigned their name. Many were named after prominent individuals, original landowners, or nearby landmarks.

"With no system of street coordinates and no baseline information, how do you find your way around a constantly growing city? How do you dispatch ambulances, firemen, and law enforcement personnel quickly? How do you send mail and messages to private homes? How do you locate urban facilities and infrastructure? How do you pinpoint breakdowns in water, electricity, and telephone systems? How do you improve on-site collection of water and electricity bills? How do you set up an efficient local tax system?" (Farvacque-Vitkovic, Godin, Leroux, Verdet, and Chavez, 2005).

### *Needs and Project Benefits*

By designing and implementing a systematic address system, cities, communities, and various stakeholders benefit immensely.

#### Government

From a national security perspective of a country which has battled civil and guerilla wars for most of its recent history since gaining independence from Great Britain in 1956, establishing a numbering system in the country will enable the government to secure and account for its citizenry in the most populated city of Khartoum.

Another benefit is the ability of various law enforcement and other agencies such as police and, fire departments to coordinate and respond to varying emergencies which normally occur in bigger cities such as Khartoum.

Other governmental agencies and entities such as health clinics and hospitals, schools, utility providers also stand to benefit from this system by increasing efficiency and maximizing their potential for providing adequate services to the public.

#### Private Sector

As for the private sector, it cannot be understated what an impact such a

numbering system will have on this influential segment of the country's overall economy. This sector is known for its desire to eliminate waste, promote and increase efficiency, better management of supply and demand resources, and the economy of scale to name a few.

Expansion in the city of Khartoum is occurring continually. For many private sector players to increase their involvement in such expansion efforts are dependent upon the security of their investment. Such security will not become possible unless the city can provide an infrastructure system which includes a unified numbering and addressing system.

Citizens

Many social and economical benefits will occur from a uniform numbering system. As for the general citizenry, knowing and having a unified system in place will help improve the quality of life for those who live in the city of Khartoum. For example, they will be able to determine the location of a specific address in a timely manner without having to guess or use verbal descriptors to navigate.

Private real estate properties are considerably undervalued due to the lack of a zoning structure. A numbering system will help in providing a legal framework to help with determining more accurate properties and property values.

NGO/Others International agencies

Many Non Government Organizations (NGOs) currently operating in Sudan and Khartoum, voice their concerns and frustration over the lack of such system in place. This hinders their efforts in helping Sudan. Further, having a numbering system in Khartoum will help entities focus on their work helping the rebuilding process within Sudan rather than wasting time and scare financial resources trying to figure out or guess where to reach prospective citizens.

Having a number routing and measurement system will make things easier for all citizens of Khartoum. The question is why has the government not yet created a system and what are the challenges to adopt such a system?

There are so many problems facing mature and somewhat older cities such as Khartoum. Financial challenges and corruption are the two major obstacles which hinder such efforts. The lack of technical and experienced human resources qualified to lead such a project is also a factor to consider. General public participation and support for such a project requires governmental agencies to take a much more active role in explaining the necessity and benefits of an addressing system to the citizens.

**Methods**

The data needed for this project included the following data layers:

1) The street layer for city of Khartoum which was downloaded from the United Nations web site.

2) The address grid layer was created using the fishnet tool which was downloaded from Environmental Systems Research Institute. The Grid layer is the main layer for the project and it represents a number of cells (Figure 2). Each cell measures (1km by 1km).

The data attributes needed for the grid layer included: Area, Maxy, Maxx, Minx, Miny, West address range, East address range, and South address range fields. All were used to define the starting

ranges for the addresses in that designated cell. The address range reference point (0, 0) starts at the North West corner of the city where the White Nile meets with the Blue Nile.

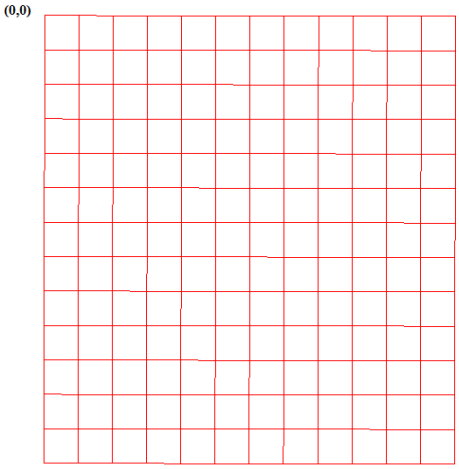


Figure 2. The Grid Layer showing the address range reference point.

For example, if W_ADD_RANGE contain 100, then it means the 1xx addresses start there and proceed west (up to 200, which would then become the start of the next cell). All addresses in this next cell will begin with 200 and be numbered sequentially until the next cell, which then will start the 300's numbering sequence. Repeating this pattern will assign addresses to all current or future buildings in a designated cell.

The E_ and W_ADD_RANGE fields define the starting ranges for the "east-west" streets only; the N_ADD_RANGE field only applies to "north-south" streets. The EFACTOR and SFACTOR fields are used for computing address numbers at a particular point within the specified cell.

By creating a custom ArcGIS program using ArcObjects and Visual Basic .NET, a customized tool was created which allows the user to calculate the exact address by placing the cursor on a specific location within the cell and then clicking the mouse on the selected location.

In order to calculate the distance from the reference line, a formula was created to return the exact coordinates of the selected location by using the EFACTOR field which represents the possible "east-west" address range for a cell, and SFACTOR field which represents the possible "north-south" address range for a cell.

The formula for computing those numbers is as follows:

EFACTOR = the possible "east-west" address range for a cell (usually 100) / the extent of the cell in the x direction (i.e. the absolute value of (MAXX – MINX)).

SFACTOR = the possible "north-south" address range for a cell (usually 100) / the extent of the cell in the y direction (i.e. the absolute value of (MAXY – MINY).

***Limitations***

The main challenge for this project was the data collection. The limited GIS data sources for Sudan made it impossible to obtain raster data set that could help viewers visualize the study area and how streets are designed.

**The Address Tool**

ArcObjects and VBA were chosen to write the script to create the tool by first creating a simple toolbar and button to run the script. Figure 3 shows how the Address Tool appears on the Toolbar.

The first part of the code is a mouse up event which is a public sub called UIToolControl mouseup (Figure 4). It is used as an Identifying method to get

the “FeatureIdentifyObject” objects at the mouse-click location.

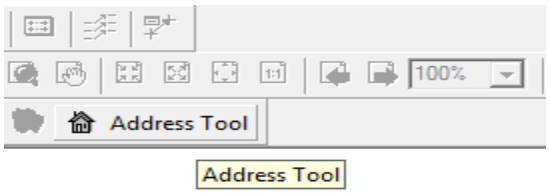


Figure 3. The Address Tool showing on ArcMap.

Then, using the IIdentifyObj interface, the code will check to verify the left mouse button is clicked. Once verified, the code will get the user’s current location on the map extend.

```
Public Sub UIToolControl1_MouseUp(ByVal Button As Long, ByVal Shift As Long,
ByVal x As Long, ByVal y As Long)

  Dim pMxApp As IMxApplication
  Set pMxApp = Application

  Dim pMxDoc As IMxDocument
  Set pMxDoc = ThisDocument

  Dim pPoint As IPoint
  Set pPoint = pMxApp.Display.DisplayTransformation.ToMapPoint(x, y)
  'Set pPoint = pMxDoc.CurrentLocation

  Dim dX As Double, dy As Double
  dX = pPoint.x
  dy = pPoint.y

  'Call ReturnGridAddress("ADDRESS_GRID", dX, dy)
  Call ReturnGridAddress("GRID_UTM36N_WGS84", dX, dy)

  'MsgBox "Mouse click at: " & vbNewLine & _
    "dX: " & dX & " feet, Y: " & CStr(Y) & vbNewLine & _
    "dY: " & dy & " feet, X: " & CStr(X), vbOKOnly, "Coordinates"

End Sub
```

Figure 4. The mouse up event.

The second part of the code (Figure 5) function was to search for the Grid Layer in the Table of Contents (TOC) for the layer of interest. Then the computed actual address was located and a point was added on the desired location.

Next, the second part of the code applies the addressing formula which calculates the exact location. Its function is to calculate the East-West address range and the North-South address range (Figure 6).

```
Private Function UIToolControl1_ToolTip() As String
  UIToolControl1_ToolTip = "Address Tool"
End Function

Private Sub ReturnGridAddress(strLayerName As String, x As Double, y As Double)
  'Used to calucate theoretical addresses using the address grid

  Dim pMxDoc As IMxDocument
  Set pMxDoc = Normal.ThisDocument
  Dim pMap As IMap
  Set pMap = pMxDoc.ActiveView

  Dim pPoint As IPoint
  Set pPoint = New esriGeometry.Point
  pPoint.PutCoords x, y

  Dim tileNameIdx, WestAddRangeIdx, SouthAddRangeIdx, EastAddRangeIdx As Integer
  Dim MinXIdx, MinYIdx, MaxXIdx, MaxYIdx, eFactorIdx, sFactorIdx As Integer

  Dim westAddRange, southAddRange, eastAddRange As Integer
  Dim minx, miny, maxx, maxy, eFactor, sFactor As Double

  Dim eAdd, wAdd, sAdd As String

  'find the layer
  Dim iLoop As Integer
  Dim foundLayer As Boolean
  For iLoop = 0 To pMap.LayerCount - 1
    If UCase(pMap.Layer(iLoop).Name) = UCase(strLayerName) Then   '<------ layer found
      "###Now preform point on polygon selection###
      Dim pFeatLayer As IFeatureLayer
      Set pFeatLayer = pMap.Layer(iLoop)
      Dim pFeatClass As IFeatureClass
      Set pFeatClass = pFeatLayer.FeatureClass

      Dim pFilter As ISpatialFilter
      Set pFilter = New SpatialFilter
      With pFilter
        Set .Geometry = pPoint
        .GeometryField = "SHAPE"
        .SpatialRel = esriSpatialRelIntersects
      End With
```

Figure 5. Showing the second part of the code.

```
        'Compute "east" address
        If Round(Abs(((x - minx) * eFactor) + eastAddRange), 0) < 100 Then
          eAdd = "0"
        Else
          eAdd = CStr(Round(Abs(((x - minx) * eFactor) + eastAddRange), 0))
        End If

        'Compute "west" address
       ' If Round(((maxx - x) * eFactor) + westAddRange, 0) < 100 Then
         ' wAdd = "0"
        'Else
         ' wAdd = CStr(Round(((maxx - x) * eFactor) + westAddRange, 0))
        'End If

        'Compute "south" address
        sAdd = CStr(Round(((maxy - y) * sFactor) + southAddRange, 0))

        Dim strAddress As String

        If eAdd > 0 Then
          strAddress = "    East-West Address: " & eAdd & vbNewLine & vbNewLine & _
            "North-South Address: " & sAdd
        ElseIf wAdd > 0 Then
          strAddress = "    West Address: " & wAdd & vbNewLine & vbNewLine & _
            "North-South Address: " & sAdd
        End If

        MsgBox strAddress, vbOKOnly, "Address.."

        Set pFeature = pFeatureCursor.NextFeature
      Loop
      'Debug.Print outString

      Set pPoint = Nothing

      Exit Sub
    Else
      foundLayer = False
    End If
  Next
```

Figure 6. Showing the formula used to calculate the address range.

## Analysis / Case Study

In Sudan, people do not refer to maps or atlases to find directions to their destinations; people typically ask a passerby for the right directions. The answer is usually given in one of these terms, "behind the big building," "in front

of x shop," "to the left of the tree," or "to the right of the field," "north of mosque," etc. Using landmarks is a definitive way for giving directions.

The act of attaching "landmarks" to the address as a "location identifier" is good. But when the information needs to be exchanged over a larger domain, it becomes necessary to formalize or standardize the address system to describe the location of a house or a building in order to ensure the accompanying data are communicated effectively and interpreted without ambiguity (Sergeant, 2002).

From personal experiences and a local example, on a quiet night in May, 2000, residents of a Khartoum suburban neighborhood were awakened by someone calling for help. As neighbors rushed to the streets, the screaming was getting louder. The house on the corner was engulfed with flames coming from the windows. Miraculously, with the help of the residents, victims were rescued unhurt. While everyone was trying to put out the fire, one of the residents was on the phone with the fire department, giving directions to the burning house. The man was sweating and walking back and forth giving these detailed directions, "turn right by the big mango tree, take another right at the corner store, then left by the two story green house", etc.

Using water hoses and sand from the construction site across the street, a struggle began to prevent the flames from expanding to the rest of the neighborhood. The clock was ticking and a little progress had been made by the residents and neighbors trying to contain the fire. The smell was strong, the smoke was getting heavier, and the atmosphere was masked with fear and frustration. The roof of the first room where the fire started collapsed and there was still no sign of a fire truck. Another resident got on the phone with 999 (the emergency call number) and started giving directions to the scene again. The fire spread to the entire house with the wind beginning to blow the fire and the house furniture fueling the flames. The roof from the second room crumbled shooting ashes and sparks high in the air.

Finally the fire truck arrived. Within fifteen minutes, the fire fighters were able to fully contain and extinguish the fire. That was too little too late because there was nothing left standing but the brick walls. The people were angry at the fire fighters. They asked, "What took you so long? It has been more than one hour!" shouted one man. The fire fighters' team supervisor told the angry crowd they were given wrong directions the first time, otherwise things would have been different and they would have saved the house.

Without providing any street name or house and/or block number, the arrival of the fire truck to the scene of the fire on-time was near impossible – it would have been only a matter of luck. Verbal directions are the typical way in which directions are given in the case of any emergency or fire. This unreliable method is the only system citizens have presently to call for help in the event of a fire or other emergency. No one can blame the fire fighters for the loss of the house, but the system is one to explore further.

Not only the fire department, but the police department, the postal service, and the health care system are all suffering from the lack of an effective city address system. If an address system is put in place, it will save lives, money, and make things less complicated for a big city like Khartoum. This will contribute to the city's economic growth because not only the public sector, but also the private sector will benefit from the existence of an effective address system in terms of timely

delivery of goods and services as well as fuel efficiency and better customer service.

## Results

The output of this application creates a message (Figure 7) that appears after selecting a specific location to get the address which will show the East-West address and the North-south address for the selected location.

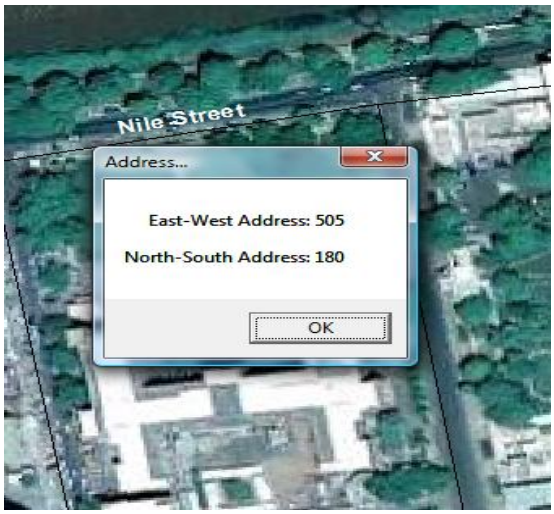

Figure 7. The message showing the East-West address and the North-south address.

## Conclusions/ Discussion

This paper intended to explore the solution GIS can provide to solve the current address problems in city of Khartoum and to establish a uniform system which assigns numbers to dwellings, buildings, and businesses. Ultimately, this would enable the city of Khartoum to facilitate emergency services, deliveries, and to provide the general advantages of a uniform addressing system. One of the most important, noticeable, and common attribute of developed countries is their well established infrastructure in place which facilitate and support the desired growth of such countries and communities. The lack of such well established infrastructure is permanent on most, if not all underdeveloped countries and communities including Sudan, and Khartoum in this case.

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