Planning Routes Dynamically with Geo-Referencing Tools

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ABSTRACT:

The planning of pipeline routes in both urban and rural environments introduces complex inter-relationship and potential conflicts with various utilities, environmental features, crossings, sites and sizing of appurtenances and structures along the alignment. Many engineers/planners begin the pipeline planning process with a desktop study of a potential route utilizing topographic maps, aerial photography and utility research. However, the alignment inevitably changes after an engineering and environmental alignment walk through, oftentimes the alignment experiences several iterative renditions.

In lieu of rolling up all the maps and information and heading out to the field, a digital data collection device that operates on a Smartphone with geo-referencing capabilities was utilized. The device digitally records real time alignment changes that are dynamically made in the field as observations are made and noted during the walkthrough. Additionally, the device allows for speech to text notes as well as photographic documentation to be developed, logged and geo-reference to any spot along the alignment. The use of real time logging and geo-referencing greatly increases accuracy of field notes and observations documented in the field.

This paper will provide an overview of the software utilized in addition to describing the applications and potential uses of geo-referencing devices as real time data loggers for future operation and maintenance of the pipeline system.

INTRODUCTION:

The population of the Dallas/Fort Worth (D/FW) Metroplex is expected to double within the next fifty years. The escalating water demand for D/FW, in combination with an aging infrastructure, expands the need for pipelines and the rehabilitation of existing pipelines. Many local cities are reassessing implementation of capital improvement pipelines and infrastructure improvement projects more frequently. The increased frequency of projects has affected the time span allotted for completion of planning and analysis.

Due to the critical nature of current project schedules, the use of evolving technologies to assist in the analysis and assessment of route definition and location of water facilities is becoming more essential. The latest technology advancement to be placed into practice by engineers and planners is the smartphone. The smartphone device is utilized daily by most professionals. The application of the smartphone discussed herein is its use as a geo-referencing device applied to the collection of data. Such dynamic collection and application of data was utilized for the analysis of Tarrant Regional Water District (TRWD) Cedar Creek Wetland (Cedar Creek) discharge pipeline route.

SMARTPHONE TOOL DEVELOPMENT:

The smartphone geo-referencing tools developed for use in the application described herein can be designed to meet specific or unique needs associated with individual projects. The process is simple: the engineer or planner outlines the criteria desired to be recorded which is then translating these to the application through a straight forward programing interface. The specific program, a customized version of Open Data Kit (ODK) Collect[(1)]. (http://code.google.com/p/opendatakit/downloads/list)

, utilized these forms created for completion in the field, Figure 1. The forms are extremely flexible: it should be noted that the program utilized is tailored uniquely for each specific project and not a customization of off the shelf software. Unique information gathered during desktop analyses can be input into the form for implementation in the field, Figure 2. These created forms allow the engineer or planner to use the device at specific and key locations along the alignment. Data collected in the form, depicted in Figure 2, may include obstacles anticipated to be encountered in the field, categorized site observations, text notation or photographic documentation.

The ability to access and display date through a web based portal can also be integrated into a project through the application. For example, the device can display location maps including the pipeline alignment live on a smartphone device while actively collecting data in the field. Many other types of web-based data sources have been incorporated in the application, such as local weather station information, or USGS soils data. The use of the device to provide real-time data recording and geo-referencing greatly increases efficiency of field notes and observations.

Data collection is not limited to points: the applications allow for making notations while walking the perimeter of any large obstruction or obstacle. Cloud-based projects can automatically generate geo-referenced polygons or polylines. This is especially useful when performing initial surveys of wetland or environmentally sensitive areas and can be easily incorporated into GIS exhibits.

Figure 1 – ODK Collect Geo-referencing Tool Home Screen

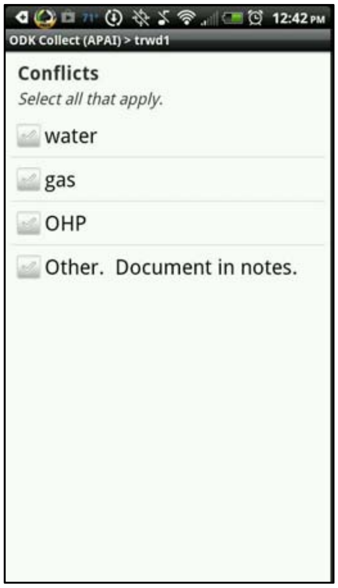


Figure 2 – Example of Unique Criteria to be Logged in the Field

The use of the Smartphone device as a geo-referenced data collection system:

- Saves time by locating approximate locations while in the field.
- Can be easily modified to collect any number and type of data sources.
- Is less cumbersome than conventional methods used today.

- Smartphone devices are abundantly used throughout the utility community.
- Accurate to a fault, dependent on the device attributes and service coverage in the area.
- Can be connected directly to other hardware devices.

DEFINING DATA COLLECTION CRITERIA:

Prior to applying the device, a desktop route analysis should still be completed to refine the alignment and determine the criteria to be collected by the smartphone device. The result of desktop analysis is criteria consisting of specific condition and critical data to be assessed and evaluated. This involves:

- Reviewing record drawings.
- Viewing aerial photography.
- Coordinating with regional utility managing entities such as the Rail Road Commission.
- Viewing and defining FEMA floodplain and floodway.
- Viewing and defining governmental jurisdiction.
- Investigating United States Geological Society data.
- Reviewing local appraisal district parcel delineations, etc.

Once research has been completed, alignment selection criteria can be determined and evaluated by using a weighted ranking system to identify the most favorable route for recommendation and further investigation. The following are common pipeline alignment selection, criteria to be considered for the tool to collect or make note of.

1. Land and Easement Acquisition
   - 1.1 Permanent & Temporary Easement/Right-of-Way (ROW) Width
2. Environmental & Archeological Considerations
   - 2.1 Potential Wetland or Mitigation Impacts
   - 2.2 FEMA. Flood Plain Delineation
   - 2.3 Potential Wildlife Impacts
   - 2.4 Archeological Findings
   - 2.5 Local Conservation Commission
   - 2.6 Aquifer Protection Districts/Zones
3. Transportation and Utility Crossings
   - 3.1 Haul Routes, Access, Staging Area Locations
   - 3.2 Department of Transportation, Railroad, City and County Road Requirements
   - 3.3 City, Gas, Electric and Franchise Utility Crossings
   - 3.4 Traffic Control
4. Engineering

- 4.1 Sizing, Flow Rates and Hydraulic Assumptions
- 4.2 Vertical Alignment Considerations
- 4.3 Tunneling, Deep Excavation and Geotechnical Considerations
- 4.4 Outfall Location

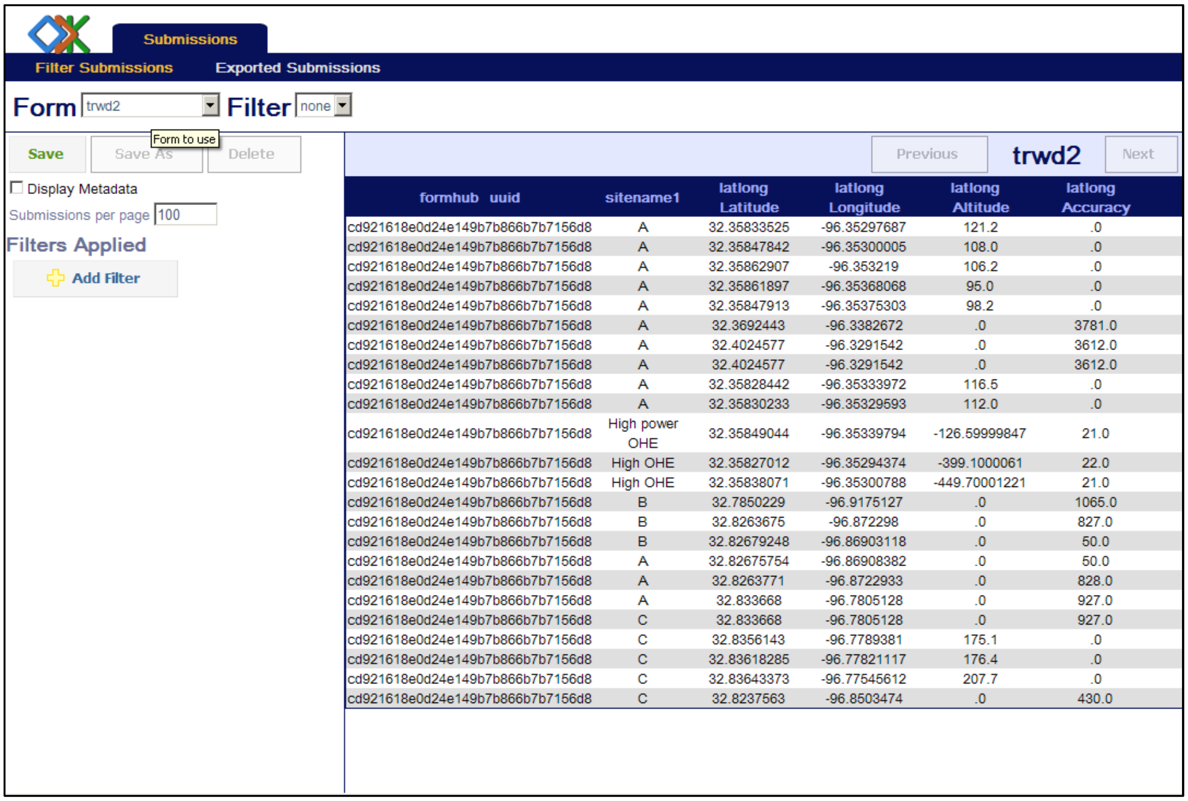
5. Capital and Operating Cost
   - 5.1 Capital
     - 5.1.1 Equipment
     - 5.1.2 Land
     - 5.1.3 Schedule
   - 5.2 Life Cycle
     - 5.2.1 Operational Cost
     - 5.2.2 Maintenance
     - 5.2.3 Energy Recovery
6. Socio-Economic Impacts
   - 6.1 Temporary & Permanent Community Impacts
7. Other – project specific criteria (e.g. client requested criteria)

Critical criteria identified as key deciding factors can be incorporated into the application for completion in the field. Criteria such as utility conflicts were added for the Cedar Creek pipeline as standard form items to be completed on-location as shown in Figure 2. Approximate latitude and longitude location is provided for each form. Once uploaded into a web-based database these criteria can be exported into a spreadsheet allowing users to sort and search data for key criteria. An example web-database is shown in Figure 3.

ACCESSING DATA:

A unique web database is created per project, which allows secure access to engineers, planners and clients.

Configuring the smartphone tool to collect the correct form and type of data is crucial *prior* to scheduling a walkthrough of the alignment. The importance for a planner/engineer to walk the alignment is to verify the identified criteria during the desktop analysis and to identify new or unanticipated obstructions to be considered during design.



formhub uuid	sitename1	latlong Latitude	latlong Longitude	latlong Altitude	latlong Accuracy
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cd921618e0d24e149b7b866b7b7156d8	A	32.35847842	-96.35300005	108.0	.0
cd921618e0d24e149b7b866b7b7156d8	A	32.35862907	-96.353219	106.2	.0
cd921618e0d24e149b7b866b7b7156d8	A	32.35861897	-96.35368068	95.0	.0
cd921618e0d24e149b7b866b7b7156d8	A	32.35847913	-96.35375303	98.2	.0
cd921618e0d24e149b7b866b7b7156d8	A	32.3692443	-96.3382672	.0	3781.0
cd921618e0d24e149b7b866b7b7156d8	A	32.4024577	-96.3291542	.0	3612.0
cd921618e0d24e149b7b866b7b7156d8	A	32.4024577	-96.3291542	.0	3612.0
cd921618e0d24e149b7b866b7b7156d8	A	32.35828442	-96.35333972	116.5	.0
cd921618e0d24e149b7b866b7b7156d8	A	32.35830233	-96.35329593	112.0	.0
cd921618e0d24e149b7b866b7b7156d8	High power OHE	32.35849044	-96.35339794	-126.59999847	21.0
cd921618e0d24e149b7b866b7b7156d8	High OHE	32.35827012	-96.35294374	-399.1000061	22.0
cd921618e0d24e149b7b866b7b7156d8	High OHE	32.35838071	-96.35300788	-449.70001221	21.0
cd921618e0d24e149b7b866b7b7156d8	B	32.7850229	-96.9175127	.0	1065.0
cd921618e0d24e149b7b866b7b7156d8	B	32.8263675	-96.872298	.0	827.0
cd921618e0d24e149b7b866b7b7156d8	B	32.82679248	-96.86903118	.0	50.0
cd921618e0d24e149b7b866b7b7156d8	A	32.82675754	-96.86908382	.0	50.0
cd921618e0d24e149b7b866b7b7156d8	A	32.8263771	-96.8722933	.0	828.0
cd921618e0d24e149b7b866b7b7156d8	A	32.833668	-96.7805128	.0	927.0
cd921618e0d24e149b7b866b7b7156d8	C	32.833668	-96.7805128	.0	927.0
cd921618e0d24e149b7b866b7b7156d8	C	32.8356143	-96.7789381	175.1	.0
cd921618e0d24e149b7b866b7b7156d8	C	32.83618285	-96.77821117	176.4	.0
cd921618e0d24e149b7b866b7b7156d8	C	32.83643373	-96.77545612	207.7	.0
cd921618e0d24e149b7b866b7b7156d8	C	32.8237563	-96.8503474	.0	430.0

Figure 3 – Web-Database

The application interface provider live web-based mapping for location referencing, while in the field, to assist field staff to reference themselves to key data points during site visits. This is a distinct advantage to the old method of using aerial photos or USGS maps and landmarks to location a spatial position. The mapping aspect of the tool allows the engineer/planner to locate themselves as accurately as the device being applied allows, in application sub-meter accuracy has been achieved.

By dynamically logging spatially-accurate observations, a great reduction in the misinterpretation of design directives is achieved. Field notation of obstacles to be avoided now includes latitude, longitude, and photographic documentation with bearing location data. Each form completed appears in numerical and chronological order within the database. This can be crucial information for designer/planning team members who may never participate in a site visit. An example of how this data can be displayed is seen in Figure 4.

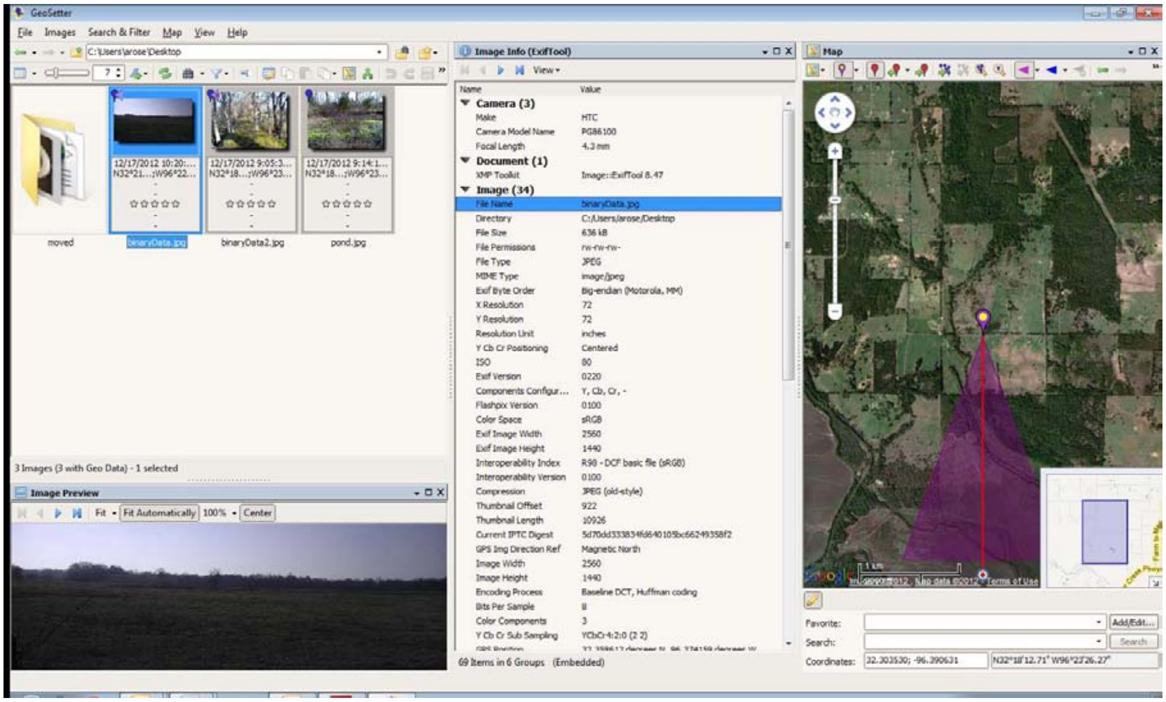

Figure 4 – Displaying Global Referencing Geo-tagged Image with Location and Direction

This new method of recording geo-referenced images is more practical than many previous methods used to document sites. Often individuals lose all perspective of location when reviewing video documentation. The ease at which this can happen is most evident in rural settings where one property cannot be distinguished from another without accurate audio records, written records or distinguishing landmarks. As seen in Figure 4 a geo-referenced photograph provides data to allow for not only latitude and longitude to be displayed, but also the direction in which the image was taken.

TOOL APPLICATION – CEDAR CREEK RAW WATER LINE:

The Cedar Creek Wetlands Discharge pipeline is an excellent case study demonstrating the utilization and application of why as they pertain to planning dynamically. The Cedar Creek pipeline runs from the future planned wetlands located 12 miles west southwest of Kemp, Texas, along the Trinity River and terminates at the Cedar Creek Reservoir. The area around the proposed wetlands comprises predominately rural agricultural land and naturally vegetated properties.

Due to the heavily wooded nature of the some portions of the area, many features where not evident during the desktop investigation and route analysis that was done while viewing aerial photography and topographical data. As shown in Figure 5, unanticipated obstacles were encountered during site investigations. The unanticipated levee is an example of topographic features encountered in the field that altered or added since the latest recording of regional topographic data.

Figure 5 shows how photographic data is presented through the application. The latitude, longitude, project name and location, altitude, bearing, date and time, are all generated automatically for every image taken. Additional information can be displayed, such as weather condition, temperature, or any other data requested, but was not included for this project.

Figure 5 - Unanticipated Levee Encountered

Additionally, the agricultural land depicted in Figure 6 provides an example where, without the geo-referencing data to give a frame of reference, it would be indistinguishable from other sites along the alignment. Figure 6 demonstrates the smartphone tool for determining route crossing location within the reference field. If landmarks are within the frame they are located at such a great distance from the device that they appear indeterminate in the photograph.

Figure 6 - Open Field Crossing Location

LESSONS LEARNED:

The lessons learned from the application of dynamic geo-referencing tools through smartphone devices:

- Execute a trial of the tool with the device to be used prior to excursion into the field. Each device is unique and required some application of the tool to troubleshoot. Smartphone devise may have the ability to geo-reference photos, however, will not tag information in the field due to selected options within the device.
- Care should always be taken when collecting data in the field. Even with the greatly increased efficiency provided by using a geo-referenced device, bad data can lead to poor design decisions or additional costly site visits to collect corrected or missed data.
- Testing devices used in the field to collect data with a defined digital output, such as a geophysical measuring device, can also be connected to a smartphone for logging.

CONCLUSION: THE FUTURE OF GEO-REFERENCING TOOLS:

The use of smartphones to collect geo-referenced data has been used on multiple occasions to great success. The major advantages of using geo-referencing tools with a smartphone device:

- Active real-time mapping, allowing the user to track where they are, where they have been and to plan where they are going all on the fly while in the field
- A reduction in the amount of material necessary to conduct a walkthrough of potential alignments. The smart phone replaces the aerial photography, the alignment maps, and the note pad as well as the necessity of a digital camera. Due to the frequency in which we use our Smartphone devices we are continually aware of their condition. No longer are there questions regarding whether the equipment to be used has batteries or if in complete working order.
- Depending on the number of participants there is potential for multiple sources of geo-referenced data which can be easily compiled and sorted for comparison or cross-reference etc.
- Data can be used to incorporate into other database software and utilize for maintenance, monitoring of existing assets and planning for future projects.
- Fewer and more efficient site visits has led to savings of up to 40 percent on some active data collection projects by the authors.
- The authors have used the referenced tool to collect more than 2000 points on projects throughout Texas and Oklahoma.

REFERENCES:

(1) Open Data Kit Collect (v 1.2.2) [software]. (2012). Retrieved from http://code.google.com/p/opendatakit/downloads/list