Planning Document with Live Maps Using ArcEngine

Ashwini Wakchaure[1] and Paul D. Zwick[2]

Abstract

In this study, we explore methods for creating a dynamic planning document with mapping capabilities and tools for better integration between text and spatial elements. Urban planning is spatial in nature, and therefore maps are an integral part of the most planning documents. However, maps contained in a planning document are static images of actual maps. If these maps can be live, and if they can be accessed from a planning document, then planners can communicate spatial information in a much better manner. We worked with ArcEngine, and Microsoft Word, to create an embedded GIS application in the Microsoft Word, that connects each map in a document with an actual map (mxd) document. We also integrated linking capability between text selection and selected features, layers or maps in the document, and built a 'find in spatial data' functionality that works with text selection and layer data tables.

Introduction

This study developed methods for creating a map-enabled planning document with mapping capabilities to support the task of comprehensive plan review. Urban planning is spatial in nature, and therefore maps are an integral part of most planning documents. If maps contained in a planning document are interactive, and if they can be accessed directly from a planning document, then the planners can convey spatial information in a much better manner. This study was set in the context of comprehensive plan review, and functionality of the map-enabled planning document was derived from the mapping needs of comprehensive plan review process. The central research question of this study was whether a map-enabled planning document comprising of interactive maps and mapping functionality could be created and whether such a document would be useful in the review process. As part of this study, a prototype of a map-enabled planning document was developed using embedded GIS technology, with the ArcEngine software and the Microsoft Word software.

Literature Review

The literature review primarily involved a search for applications that supported interactive maps or demonstrated an integration of map data with textual data in a document. The search for applications similar in concept to that of a map-enabled planning document brought up

[1] Ashwini Wakchaure recently completed her Ph.D. education from the Department of Urban and Regional Planning in College of Design, Construction and Planning at the University of Florida.
[2] Paul Zwick is the Associate Dean for Research & Graduate Programs, Ph. D. Director and the Director of GeoPlan Center at the College of Design, Construction and Planning at the University of Florida.

two interesting applications, namely the “ePlanning” application developed by the Bureau of Land Management (BLM), and the “participatory GIS” application developed by Voss et al (2004).

The e-Planning application’s version 1.0 (Bureau of Land Management, 2004) allows users to insert hyperlinks pointing to relevant maps in their documents. The linked maps are then displayed through a web GIS application maintained by the BLM, and are brought up in the same state (layer arrangement, scale etc.) present at the time of linking. Maps also contain links to textual portions in the document, and by clicking on linked map features one can view text associated with that link in another window. This application demonstrates one way in which text and map data can be linked in a web-based environment.

The participatory GIS application is developed using a combination of applications namely the “DITO” application and the “CommonGIS” application. “Dito” sets up online discussion sessions and allows interaction among various participants, and “CommonGIS” conducts GIS analysis, and supports result visualization. Linking between maps and discussion sessions is achieved with annotations present in a map. Annotations in a map are linked to relevant discussion sessions, and a user can activate a map by clicking on the annotation icon next to a linked discussion session, or the user can query a map feature to display all the discussions associated with it. The participatory GIS application is novel in the sense that it demonstrates use of links between maps and comments in an online discussion setting.

Besides these examples, other examples were also reviewed in order to understand how linking between text and map data could be achieved, and to identify the technologies that facilitated development of an interactive map-enabled document. Since requirements of the comprehensive plan review process were used to define mapping needs of a map-enabled planning document, this process was examined in sufficient detail. The mapping tools identified as necessary to support the purpose of review consisted of tools for manipulation of map display, and other functions essential to conduct basic GIS analysis such as attribute and spatial queries, buffer, spatial selection, addition of local data to maps and the ability to save maps.

Technology Selection

To implement the concept of a map-enabled planning document various GIS technologies were examined. Based on each technology’s ability to support text and map data integration, and the range of GIS functionality supported, web GIS, open source GIS and embedded GIS technologies were identified as candidates to develop a prototype of the map-enabled planning document. Upon further examination, open source GIS technologies were not considered feasible for prototype development due to concerns of implementation such as specific server requirements, possible difficulties in interfacing with word processing software, and the potential lack of technical support. Web GIS technologies, on the other hand, offered advantages of a web-based environment such as the ability to connect with text data using hyperlinks, use of a

browser to display maps and concurrent support for multiple users. However, the disadvantages of web GIS software included access to limited GIS functionality and inability to maintain the state of maps when maps were opened through links. The web GIS technology does not support advanced spatial queries such as within, or intersection between features, it does not support saving maps in the “mxd” format and legend alteration for layers is usually not supported.

As against these characteristics of web GIS, embedded GIS technology offered advanced range of GIS functionality including saving of maps in the “mxd” format, support for spatial queries, and so on, mainly because any custom GIS functionality can be programmatically developed with the embedded GIS technologies. Also, with the use of embedded GIS technology, GIS functionality can be integrated in other software such as Microsoft Word and this feature of embedded GIS technology offered a much better prospect for linking map data and text data in a map-enabled planning document. Therefore, embedded GIS technology was chosen for implementing a prototype of a map-enabled planning document.

Details of Prototype Implementation

The prototype was created using ESRI's ArcEngine software and the Microsoft Word software. In the prototype, appropriate GIS functionality is embedded within the Microsoft Word software, primarily because most planning documents are prepared with the Microsoft Word software, and planning personnel are familiar with it. The prototype was initially developed with ArcEngine 9.0 (current software at the time of development), Microsoft Word 2000, and Microsoft XP as the operating system. However, later, the prototype was modified to make it compatible with ArcEngine 9.2 (ArcGIS 9.2 suite) and Microsoft Word 2003. The prototype is also compatible with ArcGIS 9.3 desktop products and Microsoft Word 2007 (in the compatibility mode) on the Microsoft Vista operating system. A valid ArcEngine license is required for using this application, although systems that have a valid license for ArcMap, or ArcEditor or ArcInfo software do not require additional ArcEngine license.

The prototype was developed using the Visual Basic for Applications (VBA) language exposed via macro functionality in the Microsoft Word software. The prototype was packaged as a Microsoft Word document template that can be used to create new map-enabled documents. The template adds an additional menu item titled “Map Related” to the main menu bar in the Microsoft Word software, and the “Map Related” menu offers access to map related commands such as New Map, Open Map, Show Map Links and so on through its sub menus.

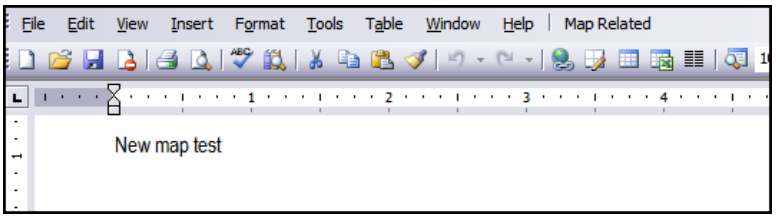

Figure 1. Map related menu item addition

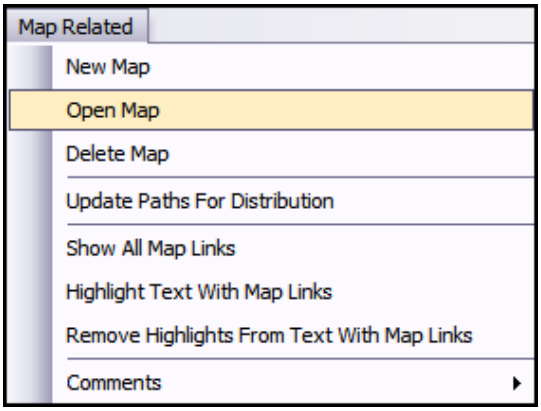

Figure 2. Map related commands

Wherever relevant some of these commands are also available from the right click context menus in Microsoft Word. For instance, if some text is selected in the document, then additional commands such as “Link Text to a Map” or “Link Text to a Layer” appear in its right click context menu. All the map-navigation and map-modification commands are available through the map dialog which is used to display maps.

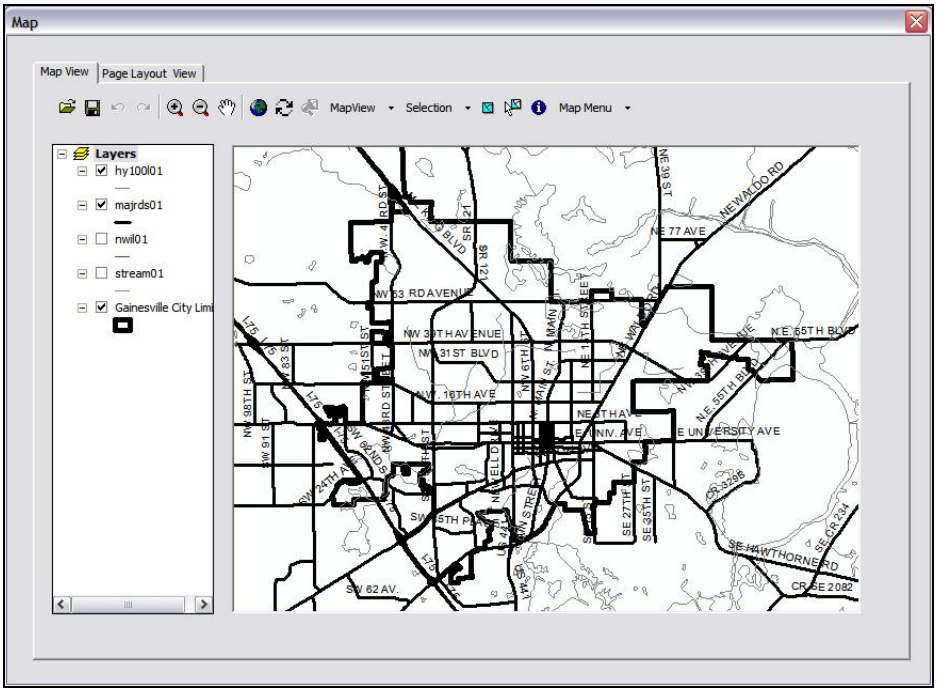

Figure 3. Map dialog box

Maps can be inserted in a word document with a “New Map” command. Each inserted map is identified in the word document by a user specified unique map name. Map details such as map name, associated mxd document name and path, number of feature layers etc. are stored in the word document in document variables. Whenever the “Open Map” command is invoked,

map details are retrieved from document variables and appropriate map is displayed in the map dialog window. Maps inserted in the document can be updated with the “Update Map” command, and the “Insert Map Image” command actually inserts a map in the document. Since maps are saved in the “mxd” document format, information about a map’s display such as its scale, legend and layer visibility is saved along with the map. The map dialog window offers two views of a map, a map view and a page layout view. Most commands related to map-modification are available in the map view, and only the commands specific to a page layout are available in the page layout view.

Mapping Commands

ArcEngine software offers very few built-in commands for direct use on its toolbar control. Some of the examples of built-in commands are commands for zoom, pan, selection of features, identify, measure, open map and save map. There are no built in commands for other functions like moving layers, making layers selectable, exporting features from layers, executing attribute and spatial queries, altering layer’s legend or labeling features. Therefore, it was necessary to programmatically build these commands in the prototype for use with maps. Many of the commands required design of a user interface as well, and these were built in similar fashion as those available with ArcMap, although some changes were necessary to minimize the number of forms involved, and to provide the desired functionality.

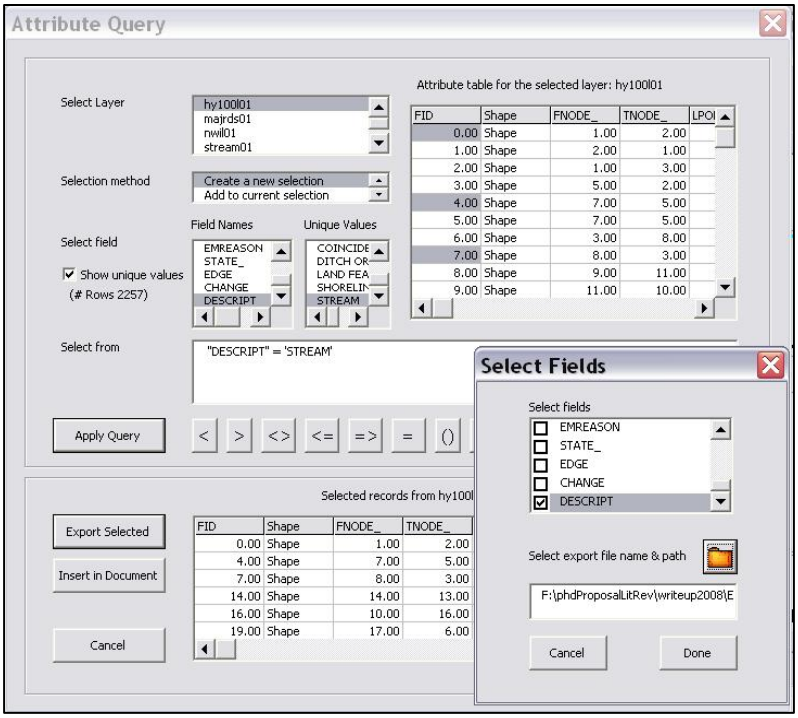

Figure 4. Attribute query dialog box

The prototype supports attribute queries and spatial queries. Queries require a layer selection, and the query expression can be formed by selecting appropriate field and associated values. Tabular windows in the attribute query dialog box show layer attribute tables associated with the selected feature layer and they can also display records selected by the query. Queries also support multiple selection methods available in ArcMap software such as “Add to the Selection”, “Create New Selection” and so on. In case of attribute queries it is possible to export selected records as a table in a comma delimited value file format (.csv), which can then be opened in spread-sheet software like Microsoft Excel or any other standard database software. Attribute query results can also be inserted as a table into a word document. In case of spatial queries, selected features can be exported into another shape file.

It is possible to create graphic or feature buffers for selected features in a map. In case of feature buffer generation, a new shape file is created containing feature buffers. Graphic buffers are temporary in nature, and can be deleted. Layer symbology can be altered in the prototype and five types of rendering techniques are supported, namely, simple rendering with a unique symbol, unique value rendering, dot density rendering, proportional symbol rendering based on attribute values in a selected field, and bar chart rendering based on attribute values from selected fields. Labeling functionality is also present in the prototype; however advanced rules of aligning, placing or orienting labels are not supported. The prototype supports addition of local data to the maps present in a document. This functionality was particularly useful for the purposes of comprehensive plan review, because reviewers could add their data to maps inserted in the document and carry out additional analysis.

Linking Tools

One of the objectives of the map-enabled planning document was to facilitate better integration between text and spatial data. A linking mechanism between text and map data was developed to achieve this objective. The linking mechanism works with a text selection in the document and one of the spatial elements; a map, a layer or a feature or features. Thus, three types of links can be created namely, a layer link, a map link or a feature link. A layer link is a link where the selected text is linked with a feature layer that has been referenced by one of the maps inserted in the document. A map link refers to a link where the selected text is linked with one of the maps inserted in the document. A feature link denotes a link between the selected text and the selected feature or features in any one feature layer that has been referenced in the document by one of the maps. More than one links may be developed with the same text or the same spatial element (layer, map or features).

The linking mechanism can be used to enrich the document content with spatial references wherever necessary. For instance, all occurrences of word “Gainesville” in a document can be linked to the feature layer containing the Gainesville city boundary. Similarly words “Trail network” can be linked to a map of trails inserted in a document. Words defining a particular feature such as “Paynes Prairie creek” may also be linked to actual creek features in

the “Creeks” layer. Presence of such links can facilitate improved understanding of the spatial context of the linked content in the document.

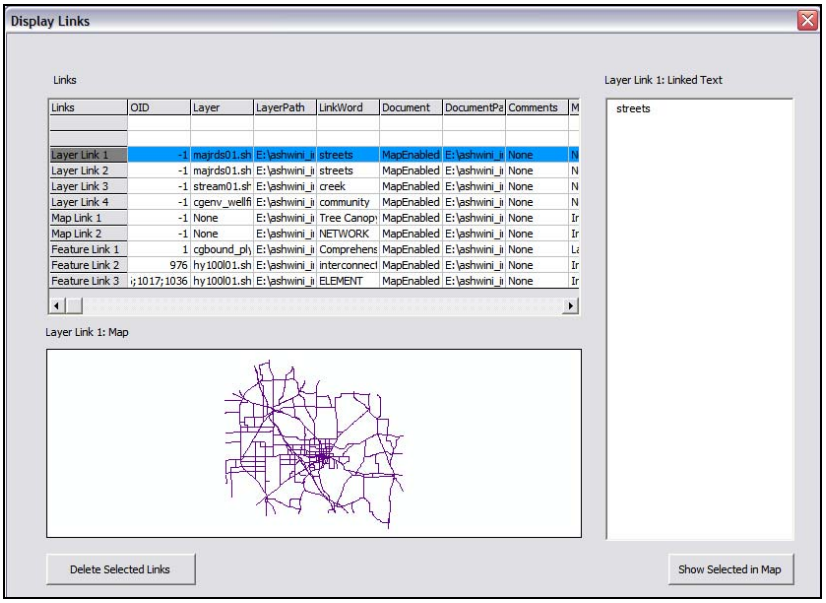

Figure 5. Display links dialog box

Search Tools

Search for selected text in spatial data referenced by the document was facilitated through two types of search tools, one being the “Find in Layer” command, and another being the “Find in Map Data” command.

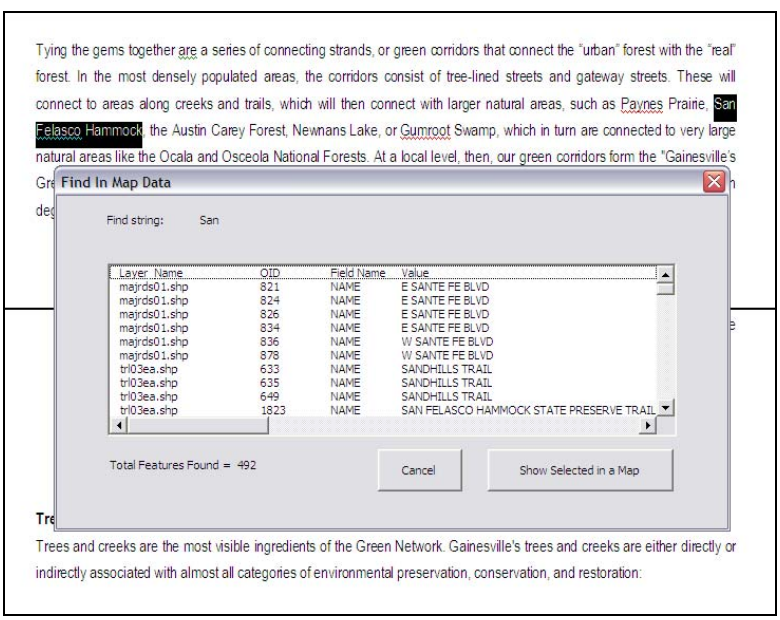

Figure 6. Search for text in maps

The “Find in Layer” command works with a text selection in the document and a layer selection made from a list of feature layers referenced by maps inserted in the document. For instance if the words “Paynes prairie trail” are selected in a document, and the “Trails” layer is selected by a user when presented with the list of layers, then this command executes an attribute query on every string (text) field of the “Trails” layer’s attribute table, and locates values containing the selected string as well as some of its variations (use of like, % operators is included in the search string). A list of results is presented to the user along with the field name in which results occur. From the results list, the user can further choose to view features associated with a particular result, in a map.

This command is useful in two ways, first, even a user having no knowledge of spatial data included in the map can execute this command and see if a feature exists in relation to the selected text and view it further on the map. The other reason for this command’s usefulness is that in the absence of such a command, the user will have to execute a complex attribute query in a map view having format “field1” = “Searchstring” or “fieldx” = “Searchstring” for all the fields in a particular layer. To execute this query on all the layers referenced by all the maps in a document, the user will have to execute it individually on each layer by opening all the relevant maps included in the document. However, with the search command “Find in Map Data”, the user can just have a text selection in a document and execute a search across all the referenced layers, and all the text fields present in each layer. After finding the first 500 results, the execution of the query stops. If necessary, the user may limit the search to a single layer, or redefine the search string to obtain fewer results. Search tools can be useful for developing links. With search tools, users may look for occurrence of particular text content in map data and if found relevant, they can create links with appropriate spatial content.

Tools to View Linked Content

Provision of tools for linking text and spatial content in the document allows authors of the document to create spatial references in the text with appropriate links. The user can then access information about all the links in the document with the “Show All Map Links” command. This command brings up a dialog box that displays link information such as linked text, image of the linked feature, layer or map and other information such as the object ID of the linked feature, layer name and path, map name and path and so on wherever applicable for all links. Moreover, there is a command “Highlight Text with Map Links”, which highlights all the linked text in the document. This makes it easier for the user to know as to what text in a document is linked with spatial information. To view link information for linked text the user can select the linked text and execute a command “Show Map Link for Selection” from the right click context menu. The user can also choose to remove highlights from the linked text with another command, for better readability when necessary.

Commenting and Document Distribution Tools

Since the prototype of a map-enabled planning document was developed to aid the task of comprehensive plan review, it was expected that a number of reviewers would access comprehensive plan documents and comment on planning issues. Therefore tools to set commentator information and to compile a comment table listing all commentators and their comments were also created.

The prototype of a map-enabled planning document refers to variety of files that are external to the word document such as mxd files, layer related data files, and map image files representing maps in the document. It is essential that whenever a document is moved from one place to another, all the external files are still available with the correct reference information for the interactive maps to function in the desired manner. Therefore, a file management command "Update Paths for Distribution" was created. This command arranges all the datasets, map images, and mxd files associated with the interactive maps in a hierarchical folder arrangement, with the planning document's path as the root folder. For instance, after updating paths, new sub folders named maps, data and images are created in the folder containing the planning document, and relevant files associated with the interactive maps are copied in the respective folders. The conceptual folder arrangement resulting after updating paths is shown below.

..\DocumentPath\planning document.doc
..\DocumentPath\Maps\
..\DocumentPath\Maps\Data
..\DocumentPath\Maps\Images

After the correct folder arrangement is achieved with the "Update Paths for Distribution" command, in order to move the document from one location to another, the user has to copy the word document to the desired location and invoke the "Update Paths for Distribution" command again. The "Update Paths for Distribution" command not only copies files according to the desired folder arrangement but also looks for referenced files and updates their references with new paths inside the word document.

Prototype Development Constraints

The prototype was developed to demonstrate the concept of a map-enabled planning document, and to test its usefulness in the context of comprehensive plan review. Therefore, the implementation of prototype was scaled down in some areas, since incorporating complete functionality was time consuming. Most of the development constraints mentioned here are not constraints of the technology, since ArcEngine supports a large range of functionality; however considering the scope of this work and the time available, partial functionality was implemented.

Currently most commands available in the prototype document work on feature layers based on shape files only. Also, each map (mxd format) document inserted in the word document

is expected to have only one data frame. The layer information about each map is derived from this single data frame and stored in the word document variables as a reference. If more than one data frames are present in a map document, and if the active data frame changes in between subsequent retrievals of that map document, then all the map references related to that map in the word document may become invalid, hence there is a restriction of using only one data frame in a map. Another constraint is that all the spatial data referenced by the map-enabled planning document is expected to be local data, as the prototype is not designed to work with network data at this point. However, it may be useful to support use of network data in the future. As far as links are concerned, if any linked spatial content is not referenced or deleted after creation of links with text selection, then those links have to be manually deleted, because there is no direct event in Microsoft Word 2003 that can be used to detect alteration in linked content.

Prototype Testing

The prototype was tested by the GIS manager of the East Central Florida Regional Planning Council and was found satisfactory for the purposes of comprehensive plan review. They found the design of the prototype user friendly and stable, and its functionality adequate for conducting basic GIS analysis. One of the concerns raised by them was regarding the availability of the "Delete Map" command for all users of the document, and it was suggested that some mapping functionality available with the prototype may be limited to a certain group of users, such as the authors of the document. Another agency that commented on the prototype was the Alachua County's Growth Management division. Planners from the Alachua County suggested that it would be useful to access linked text on the map view, whenever linked features were selected. Both the reviewing agencies felt that the map-enabled planning document would prove to be useful for users outside the field of planning who may deal with maps.

On the whole, the prototype was well received and found satisfactory. The prototype demonstrated that the presence of interactive maps in the planning document and the ability to link map data with text data can significantly extend descriptive power of planning documents and also incorporate transparency in the review process, by bringing out relevant spatial analysis clearly through interactive maps.

Discussion

The prototype of a map-enabled planning document offers considerable GIS functionality inside a Microsoft Word document. With the embedded mapping functionality in the prototype, users can create new maps, save maps, explore spatial relationships between different datasets, perform proximity analysis, add their own data to the maps, search map data from the document, query map data by attributes and by spatial relationships, extract results of queries or selections in a tabular format or in a new shape file format for further work, create meaningful links between features, layers or maps of importance and relevant text in the document, and associate comments with the feature links. As a result of having mapping functionality and live maps in a

document, users can interact with maps included in the document and conduct some spatial analysis if necessary. Access to mapping functionality within the familiar environment of word processing software is particularly beneficial for non-GIS users since they do not need to learn completely different GIS software, and they can still work with maps on an as needed basis.

A search capability within the map data is also quite useful for non-GIS users because they do not have to understand the structure of layer data tables or syntactical requirements of executing attribute queries, but can still examine whether selected text exists in the maps inserted in the document. Presence of links between text and map data can further enhance a document's ability to convey spatial information to a user. Moreover, users can work with existing maps to include additional local data and create new maps.

A map-enabled document can also prove to be useful in other situations such as public participation meetings, or inter agency or inter department meetings where collaborative discussions about issues of spatial context may take place. In such situations participants can view maps involved in required detail, browse datasets referenced by the maps and examine spatial relationships through queries, or proximity analysis.

A map-enabled document offers a number of advantages over map sharing with the web GIS technology. Some advantages are due to the advanced querying capabilities programmed within the prototype that are not supported by the web GIS technology. Also the prototype's ability to save maps in the "mxd" format is particularly useful because maps saved in the "mxd" format can be modified at a later time; however maps saved with the web GIS technology are in image format and cannot be used for modifying existing maps or for generation of new maps. Also the web GIS technology normally does not support saving a session, therefore a map has to be created from the base map every time a new session is started. The main advantage of the embedded GIS technology over the web GIS technology is its ability to program functionality that may be absent with the web GIS technology. A benefit of the web GIS technology is that it maintains mapping data online on server. The present implementation of the prototype does not support use of network data; however current version of ArcEngine supports it. Therefore if the prototype is modified to make use of network data then that can be an added advantage in the future, because with availability of online network data, the need for distribution of spatial data with map-enabled document will be eliminated or reduced.

In ArcEngine, developers are provided with a powerful set of ArcObjects that can be used to develop custom GIS functionality. However, during the development of a map-enabled planning document prototype, it was realized that only basic map navigation tools and related commands were built-in with the ArcEngine software and everything else had to be programmed. This makes extensive development of GIS tools with ArcEngine time consuming. At the same time, ArcEngine can be quite useful in creating specific GIS tools geared towards a particular task.

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