GIS-based Intersection Inventory System (GIS-IIS):
Integrating GIS, Traffic Signal Data and Intersection Images

By
Dazhi Sun
Rahim F. Benekohal
Montty Girianna

A study conducted by
Traffic Operations Laboratory
Department of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

Prepared for
Illinois Department of Transportation

February 2005

Technical Report Documentation Page

1. Report No, FHWA-IL/UI-TOL- 15	2. Government Accession No.	3. Recipient's Catalog No
4. Title and Subtitle GIS-based Intersection Inventory System (GIS-IIS): Integrating GIS, Traffic Signal Data and Intersection Images		5. Report Date February 25, 2005
		6. Performing Organization Code
7. Author(s) Dazhi Sun, Rahim F. Benekohal, and Montty Girianna		8. Performing Organization Report No. UILU-ENG-2005-2002
9. Performing Organization Name and Address Department of Civil and Environmental Engineering University of Illinois at Urbana-Champaign 205 N. Mathews Ave. Urbana, Illinois 61801		10. Work Unit (TRAIS)
		11. Contract or Grant No.
		13. Type of Report and Period Covered Project Report 2003-2005
12. Sponsoring Agency Name and Address The Illinois Department of Transportation		14. Sponsoring Agency Code
15. Supplementary		

16. Abstract

This study developed a **GIS**-based **I**ntersection **I**nventory **S**ystem (GIS-IIS) for the signalized intersections on the state-maintained highway system of IDOT District 6. GIS-IIS is a tool to have an easy access to intersection inventory data, photographs, and videos of each approach as well as an ability to query the information. It is set up to be expended to include other types of intersection related data. Procedures were developed to field data collection and processing along with a process for integrating multimedia and other traffic signal information into the GIS framework. It is recommended to expand the scope of GIS-IIS so it becomes a statewide intersection inventory system. The methods of expanding GIS-IIS to create a comprehensive information system that incorporates information such as traffic, geometric, construction, maintenance, and intersection accident data should be studied.

17. Key Words GIS-IIS, GIS inventory system, intersection inventory data integration, traffic signal inventory system, intersection photograph and video	18. Distribution Statement		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price

`Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

Acknowledgment and Disclaimer

Table of Content

1. Introduction

In this study, a **GIS**-based **I**ntersection **I**nventory **S**ystem (GIS-IIS) is developed for District 6 of Illinois Department of Transportation (IDOT). Geographical Information Systems (GISs) are computer-based systems for the capture, storage, manipulation, display, and analysis of geographic information. GIS technologies have been widely deployed in transportation area in the past two decades. GIS-IIS provides an easy access to intersection data, still pictures, and video images of the roads approaching the intersections. The features of GIS-IIS include:

1. Multiple Source Data Integration. In the GIS framework, we have integrated geographical information about streets and intersections, traffic light information, pictures and videos of all approaches of each intersection.

2. Visualization. One still image and one short video for each approach of a signalized intersection are integrated in this system. The user can get both still and dynamic view of an intersection from all directions. The still and dynamic visualization will help decision-making process on intersection management and operation analysis.

3. SQL Query Function over Relational Database. Using the SQL built-in query function, users can retrieve different information by various combinations of query condition. For example, users can query by location, intersection name, signal control type, and detector type etc.

It is set up to be expanded to include other types of data related to intersections. District 6 data was used in developing the system because it is a mid-size highway district and had readily available intersection inventory data.

1.1. Study Objectives

The main goal of this study is to develop a multimedia inventory system for the intersections on the highway system maintained by IDOT in one of its districts. Then, it may be expanded to other districts or a statewide inventory system, if needed. The objectives of this study are:

- Display signalized intersections on the GIS street map

- Develop efficient data collection and processing methods

- Integrate multiple sources of data in GIS

- Provide relevant information on signalized intersections in GIS format

1.2. Study Tasks

To achieve the objectives outlined in the previous section, four tasks were conducted:

- Collect data (GIS files, intersection signal database, multimedia data (JPEG and MPEG files))

- Digitize intersection nodes on GIS street network

- Develop a program (in HTML format) to specify the structure of documents (JPEG, MPEG, websites, and DOCs) for retrieval (from GIS map)

- Develop procedures to extract information and analyze the spatial traffic signal data from the database (inquiry)

2. Data Collection

2.1. GIS Files

IDOT provided four GIS files for district 6 (hwy04_d6.dbf, hwy04_d6.mdx, hwy04_d6.shp, hwy04_d6.shx), and one dBase file (signaldatabase.dbf) that contained traffic signal data for District 6. These files were used to create two GIS "layers," one for street networks (polyline layer) and another one for signalized intersections (point layer).

2.2. Field Data

To collect photographs and videos for these intersections, several different processes were tried. First, the plan was to walk around each intersection in a clockwise pattern and take two pictures of each approach, beginning with the northbound approach. This process was tested on several intersections along Veterans Parkway and Wabash Avenue in the city of Springfield. This procedure was not very efficient because over the period of two hours, only four intersections were recorded. Considerable time was spent to find a place to park our vehicle and wait for the traffic to clear to be able to safely cross the street and get a good picture for each approach.

The procedure was changed to take the pictures while driving so less time is spent at each intersection. This allowed us to take pictures from the traveled lanes which were better than the pictures taken from shoulders. One person drove the vehicle and another person sitting on the front passenger seat took the pictures.

Finally, we employed a more efficient field data collection plan, which only needs one person to handle the entire field data collection tasks. The key ideas of the final field data collection plan are:

- Video tape each approach of an intersection using digital camcorder. Then in the laboratory, using PIXELA-IMAGEMIXER capture still pictures (JPEG) and short videos (MPEG) for each intersection from the digital video tape. This would reduce the time spent in the field for taking pictures and recording short videos. It also improves the safety of field data collection, because it avoids crossing streets to take pictures.

- Develop a pre-defined routing plan to visit all the approaches of studied intersections. The routing plan is site-dependent and considers the network layout, number of intersections, number of approaches at each intersection, access control on each approach, etc.

- Set up the camcorder in a proper position so the driver can turn it on or off as he/she approaches or leaves the intersections.

This data collection procedure was first tested in the city of Urbana to study the:

1) Feasibility of the procedure and whether or not one person can operate the vehicle and remotely control the video taping.

2) Quality of still pictures and short video captured from the video tapes.

3) Efficiency of this procedure in terms of time and quality of images.

Figures 1.1 and 1.2 show the routing plan to record video for all approaches of a six-intersection network. In this data collection trip, Green Street and Springfield Avenue were considered as the main streets, and Lincoln, Goodwin, and Wright St. were considered as the side streets. Other side streets are not shown in the sketch of routing plan.
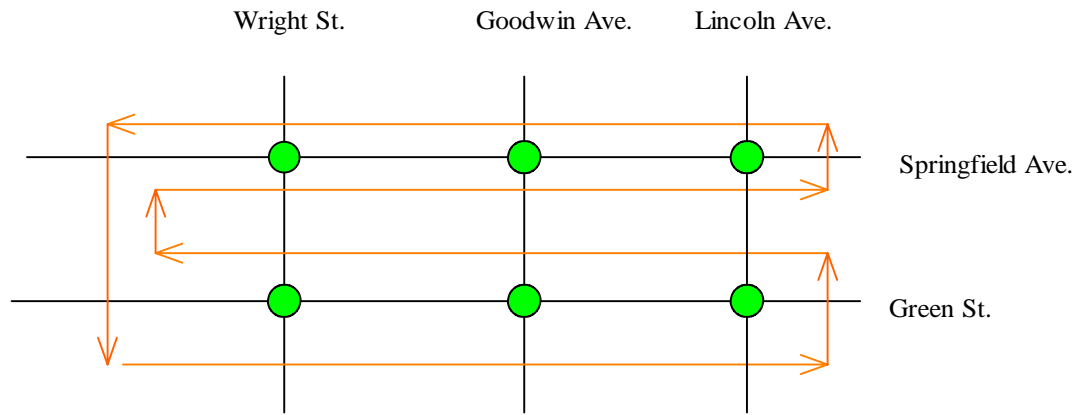
4

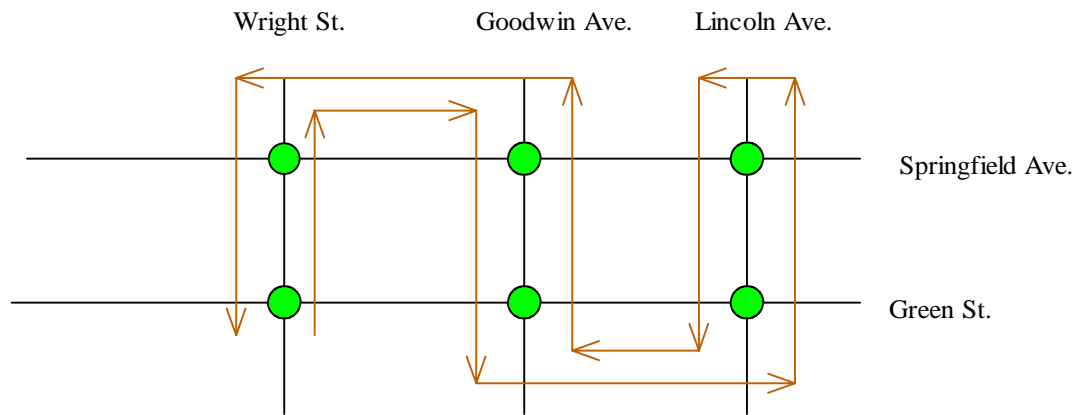Figure 1.1. Routing plan along the main streets

Figure 1.2. Routing plan along the side streets

Field test results showed that:

- Video taping all approaches of 50 adjacent signalized intersections can be completed in one day.

- One person can handle the entire field data collection tasks using digital camcorder, set on a tripod with a remote control.

- Data processing takes more time than field data collection, but it is done in laboratory.

It was concluded that the proposed data collection plan is feasible and would save time.

In this study, this field data collection plan was used to collect data of signalized intersections in IDOT District 6.

2.3. Data Processing

After the field data collection, we used PIXELA-IMAGEMIXER to capture still pictures (JPEG file) and short video (MPEG file) for each intersection from the digital video tape. The original video tapes require a large amount of computer storage space because they are in MPEG format. Normally, a 10~15 second field video in an MPEG file is about 4 ~5 MB. The video file size was reduced by using TMPGEnc-TSUNAMI-MPEG Encoder. The file size can be changed by modifying "Bitrate". Bitrate means the number of bits that go through the stream in one sec. (Stream means the MPEG file.) The higher the bit rate, the higher is the quality of the images. Another way to reduce the file size is to change the stream type from "system (Video + Audio)" to "system (video only)" format. This will significantly reduce the file size without a negative effect on video quality. So we changed stream type from "video+ audio" to "video only", and reduced bitrate by 15% at the same time (reducing bitrate too much will affect the video quality). Finally, the file size was changed from 4~5 MB to about 1.0~1.5 MB, and there was no significant change on image quality. In addition, to enlarge the displaying screen, we changed the image size from 320 * 240 pixels to 480* 360 pixels. The larger display screen is easier for the user to view the video.

3. Development of GIS-IIS

3.1. Mapping Signalized Intersections

The task is to display signalized intersections on a GIS street map and to provide relevant traffic signal data in GIS format. The signal database stored in dBase format was converted to a new data in geodatabase format. To do the conversion, first, a new layer of GIS (point class) with the same coordinate system as the GIS-street network was created. We digitized each intersection using the GIS-street network. The digitizing was made using the "ArcCatalog" menu of "ArcGIS" software. With this procedure, an empty GIS layer (called "signal layer") with the same coordinate system as the GIS-street network was created. Next, the traffic signal data stored in "signaldatabase.DBF" was uploaded to the "signal layer." The uploading was made using the "join" procedure in "ArcGIS" software.

3.2. Integrating Multimedia Data

One can access documents, pictures, or Web pages related to signalized intersections using the Hyperlink tool on the Tools toolbar of ArcMap. Thus, when one clicks a signalized intersection with the Hyperlink tool, a document or file is launched using the application with which that file type is currently associated (URL, HTML, or documents). Hyperlinks have to be defined before one uses the Hyperlink tool. One can define a hyperlink for the features in a layer using the following: 1) field-based hyperlinks and 2) dynamic hyperlinks.

Field-based hyperlinks

With this type of hyperlink, the target files (URL, HTML, documents) that will be launched is specified for each signalized intersection in a field of the layer's attribute table. One can use Microsoft Access to edit the table. The values of the field that one chooses to provide document or HTML hyperlinks to can include the full path to the target document or the full URL of the target Web page. The Hyperlink Base property is specified using Map Properties in the File menu of ArcMap. Using this property makes it easier to manage hyperlinks; if the location of the target changes one can simply edit the setting instead of having to edit each value of the field providing the hyperlink targets.

Defining field-based hyperlinks

1. In the table of contents (ArcMap), double-click the layer for which one wants to define hyperlinks.
2. Click the Display tab.
3. Check Support Hyperlinks using field, click the dropdown arrow, and select the field which contains the hyperlink targets. The field containing the hyperlink target has to be set up before one can specify hyperlinks in this dialog box.
4. Choose the Document option and the values in the selected field will be sent when the hyperlinks are triggered.

Accessing a signalized intersection's hyperlink

1. Make sure the layer containing the signalized intersection one wants to access a hyperlink for is checked on (visible) in the table of contents (ArcMap).

2. Click the Hyperlink tool. Any visible signalized intersections in the map that have hyperlinks defined for them are drawn in blue.

3. Click a signalized intersection. A hyperlink is invoked. If more than one hyperlink has been defined for the feature one clicked, a dialog will appear from which you can select the hyperlink you want to launch.

Dynamic hyperlinks

With this method, the target files (URL, HTML, documents) are specified for a particular feature in the Add Hyperlink dialog box of ArcMap. This lets one specify hyperlinks directly without having to use a field to supply the targets. The Add Hyperlink dialog box lets one specify the target files. The names of targets one specifies in this way are stored with the layer in a GIS map. They are also stored with the layer if one saves the layer to a file. One can define any number of dynamic hyperlinks for a signalized intersection. If more than one hyperlink is defined for a signalized intersection, when the signalized intersection is clicked with the Hyperlink tool a dialog will appear from which the desired hyperlink can be selected.

Defining dynamic hyperlinks

1. Click the Identify Features button on the Tools toolbar (ArcMap).

2. Click the signalized intersection for which one wants to define a hyperlink.

3. In the Identify Results window, right-click the feature and choose Add Hyperlink from the menu that appears.

4. Specify the desired hyperlink target. To link to a document, click Link to a Document and type the full pathname to the document. To link to a Web page, click Link to a URL and type in the full URL to the Web page.

5. Click OK.

Managing dynamic hyperlinks

1. Click the Identify Feature button on the Tools toolbar (ArcMap).

2. Click the signalized intersection that has the dynamic hyperlinks one wants to manage.

3. In the Identify Results window, right-click the feature and choose Manage Hyperlinks from the menu that appears.

4. Remove, add, or test dynamic hyperlinks.

5. Click OK.
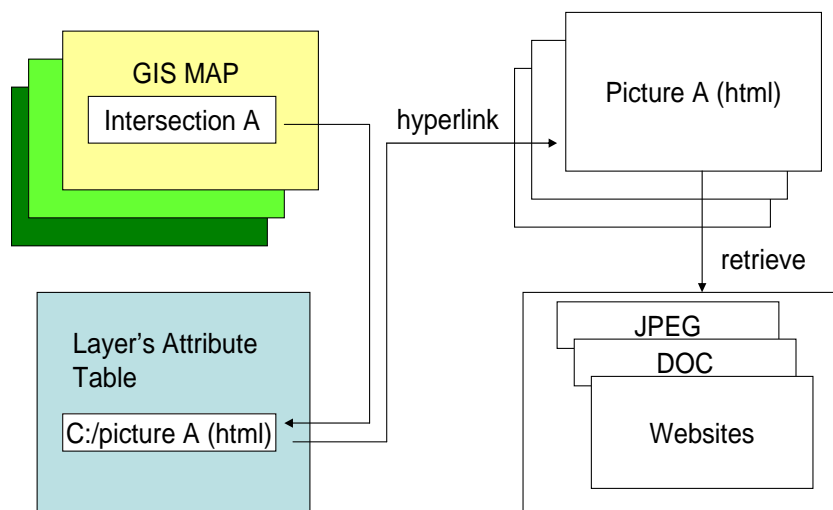
Figure 3.1 Schematic diagram of files integration

- By clicking an intersection with the Hyperlink tool on a GIS street-network map, a TARGET file is launched

- The TARGET files to be launched are HyperText Markup Language (HTML) files

- The TARGET files are specified for each intersection in a FIELD in the layer's attribute table

- The values of the FIELD include the full path to the TARGET files.

- Use Microsoft Access to edit the table

- HTML file (see figure 3.1) is used to specify the structure of documents (JPEG, MPEG, websites, and DOCs) for retrieval

3.3. Challenges in Development

There were two main challenges in developing GIS-IIS. One was about digitizing intersections. There are 242 signalized intersections in the traffic light database (signaldatabase.dbf) of District 6. Of these, as many as 177 could be directly digitized using the street network (GIS database) supplied by IDOT. The remaining (242-177) = 65 or about 27% could not be digitized directly for the following reasons.

- Some signalized intersections were identified as the intersection of two (local) streets, which were not identified by street names in the GIS database. For example, US 24 and US 67 within the city of Rushville were given local street names, which were not stored in the GIS database. Similarly, intersection of IL 16 and IL 4 in the city of Gillespie was not identified by the route numbers.

- Some intersections did not exist in the GIS database. For example, according to the GIS map, Stanford Avenue in Springfield did not intersect with 5th and 6th streets, despite the fact that the signal database listed signalized intersections at both of these locations. The reason for this is not having the GIS files for local streets.

- The intersection was new or was the access point to a commercial development that was not listed in the GIS database, for example, the intersections of Wabash and E/W Entrance of White Oaks Mall in the city of Springfield.

To digitize these intersections, we had to resort to other referencing systems, such as digital maps of Yahoo.com, or have to identify the exact location of these intersections by field trips.   This task is very time consuming.

The second challenge was to process all captured multimedia files and to create a HTML page for each intersection. The captured video files require a large amount of computer storage space. We used TMPGEnc-TSUNAMI-MPEG Encoder to modify the original MEPG files by adjusting Bitrate, stream type and display screen size. The same procedure had to be repeated about 1000 times to finish all video files of district 6. In addition, we created an HTML files for each intersection to group all multimedia files together. Video processing and creating an HTML page to integrate these files is a time consuming task, because almost one thousand of the MPEG files needed to be processed one by one.

4. How to use GIS-IIS

4.1. Installation

An auto-installation program was created to install the GIS-IIS. There are two installation

CDs. Inserting the installation CD1 to the CD-ROM, the user will see the following

Installation Window:

Figure 4.1 Auto-run Installation Program

Before installation, you can view the Readme file or browse the current CD by clicking

on the corresponding buttons. If you do not want to install GIS-IIS right now, you can

click on "Exit" button.

Click on "Install" button to continue the installation, you will see the installation dialog

window as:
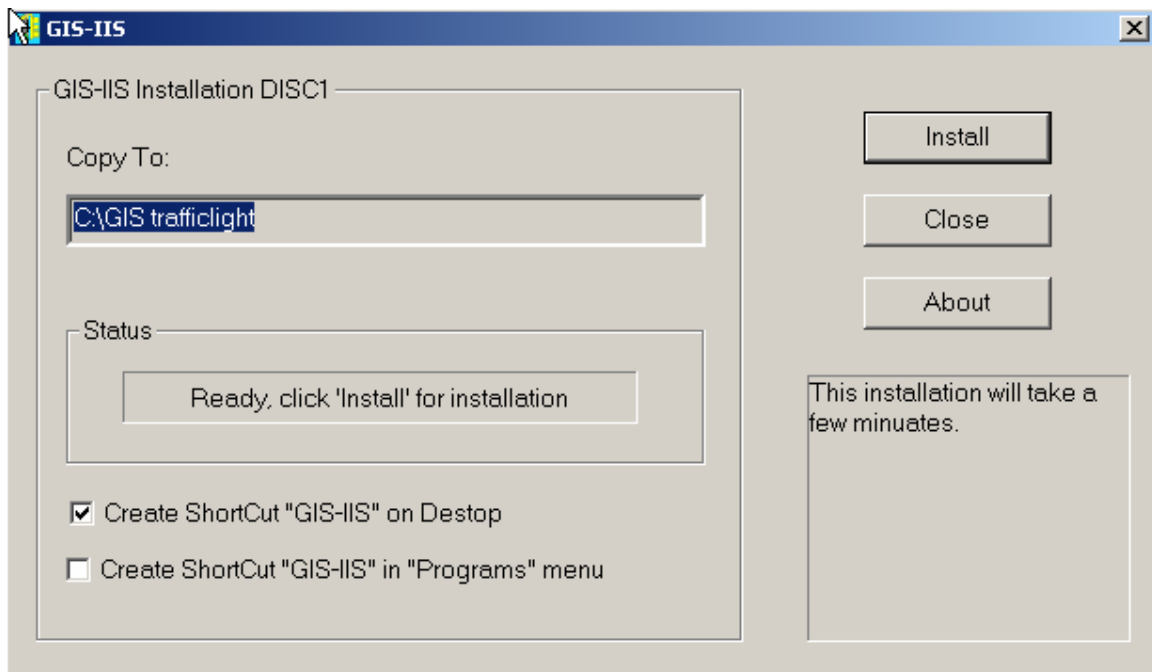
Figure 4.2 Installation Dialog Window

Within this dialog, you can choose to create a shortcut on the desktop or in the Program

menu.

Click "Install" for Installation CD 1, then you will see the next window showing the

installation status:
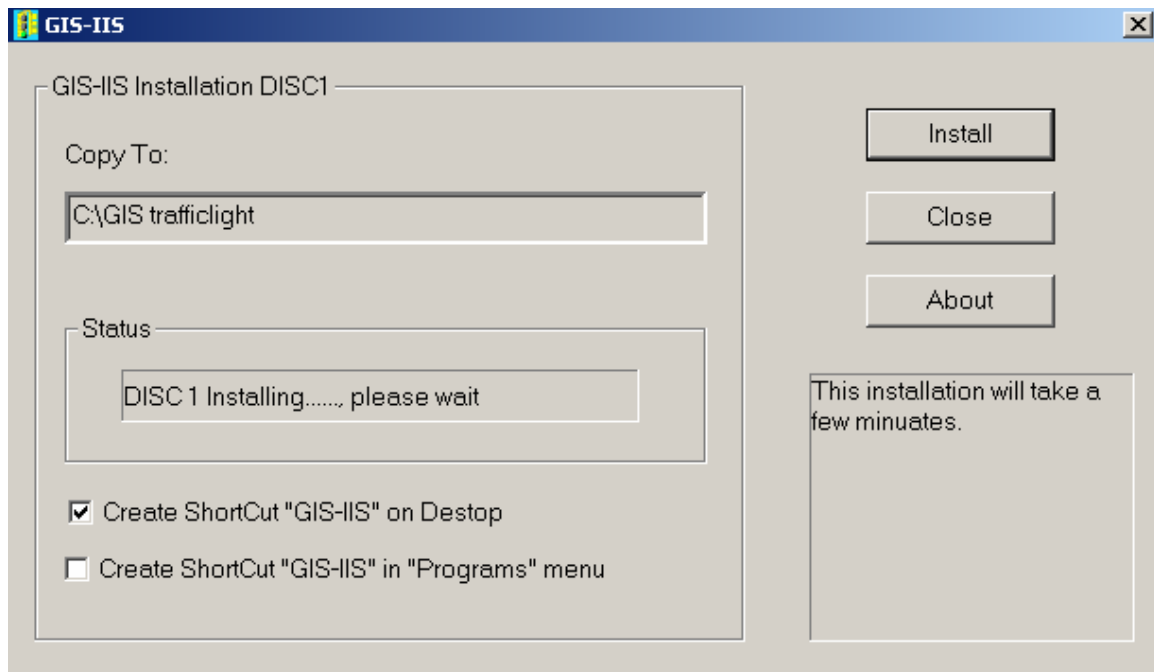
This installation will take a few minutes. When the installation of CD 1 is completed, you
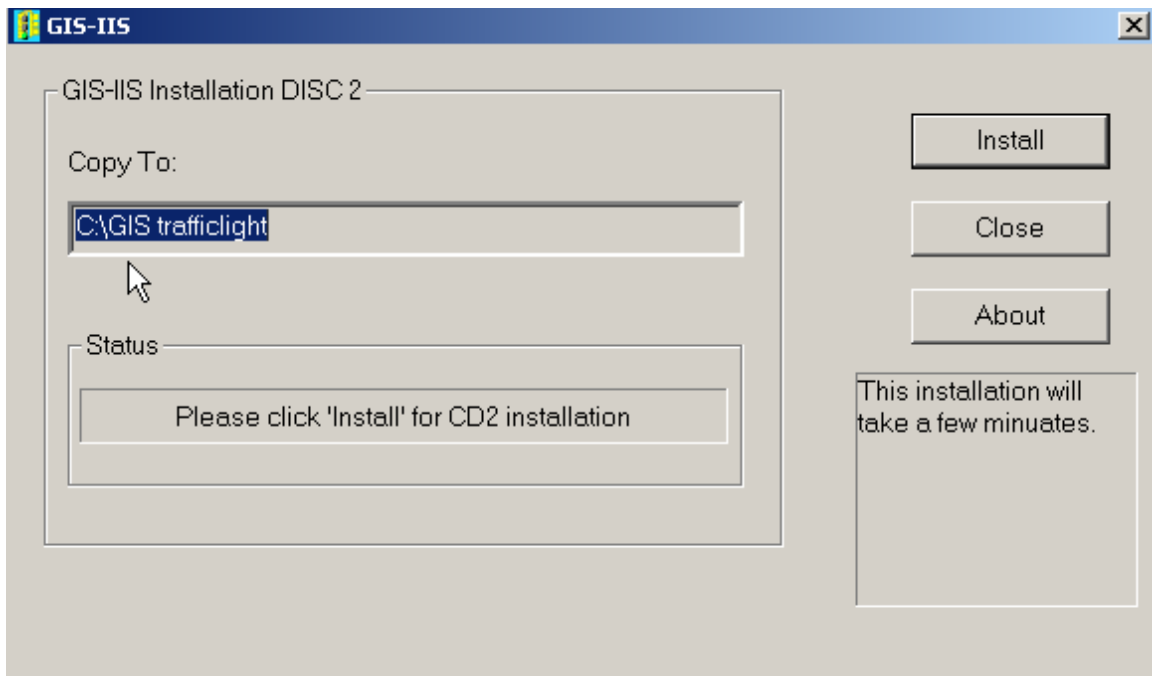
will see this window:
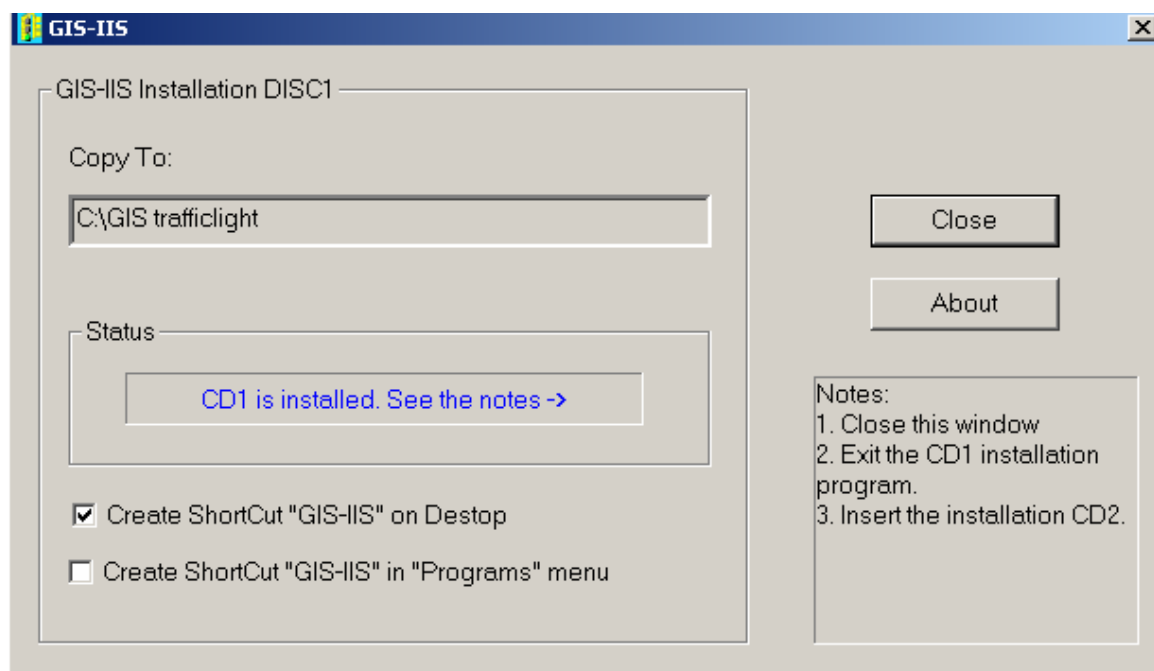
So far, the installation of CD 1 is completed. You need make sure to close this window

and exit the CD 1 installation program, then insert CD 2 into CD-ROM.

After you insert CD 2, you will see the auto-run program:

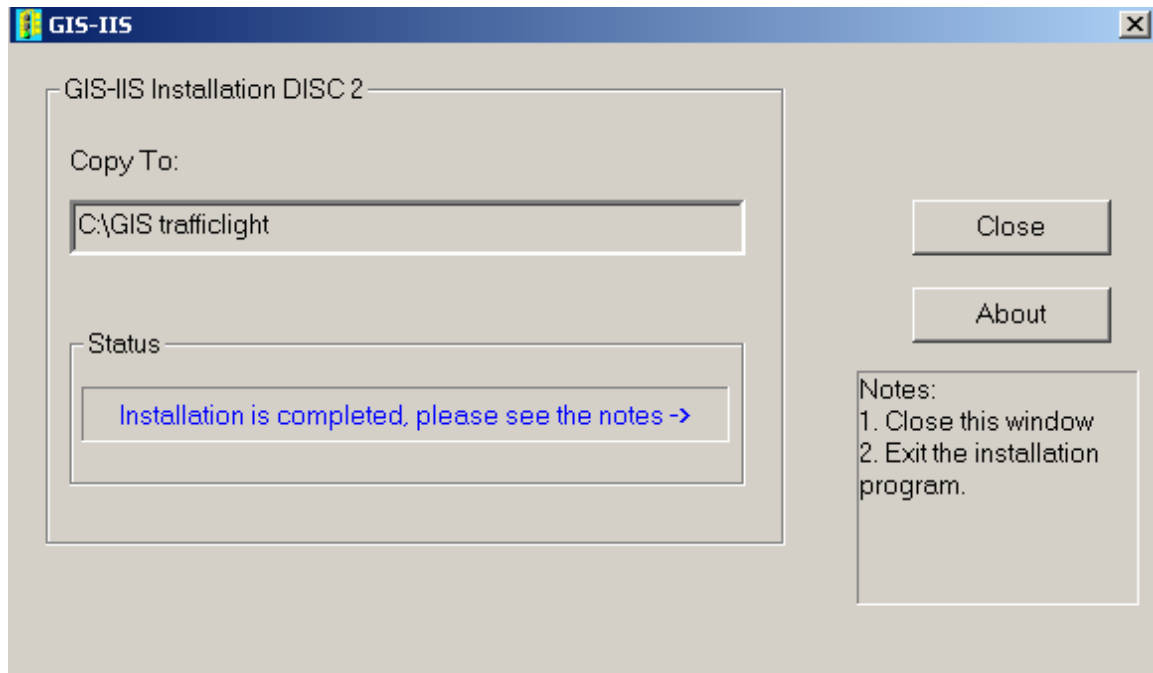Click "Install" button, you will see the next window:

Click "Install" to install CD 2 and you will see the window to show the installation status:
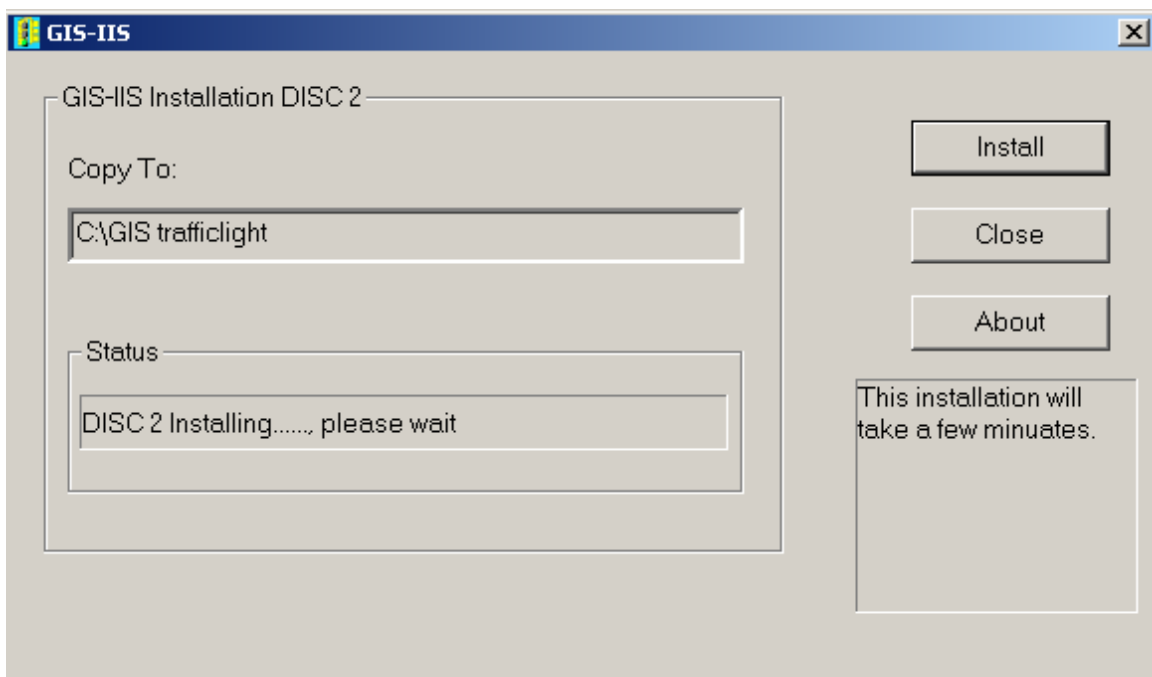
The installation of CD 2 will take a few minutes.

When the installation of CD 2 is completed, you will see the next window:

Please make sure to close this window and exit the auto-run installation program before taking out CD 2.

Now the installation of GIS-IIS is fully completed.

After the installation, you will see the shortcut of GIS-IIS on your desktop.

System Requirements:

1. ArcGIS or other GIS softwares which can view ArcMap documents

2. 1.1GB free space in disk C for GIS-IIS installation.

4.2. Application

The following two applications are shown to demonstrate the use of GIS-IIS:

1. How to display signalized intersections on GIS map

2. How to query relevant information on traffic signals in GIS format

4.2.1. How to Display Signalized Intersections

◆ Click ArcMap hyperlink toolbar, all visible intersections in the map that have hyperlinks will be shown in blue color. For example, the following pictures show signalized intersection with hyperlinks in the city of Springfield.
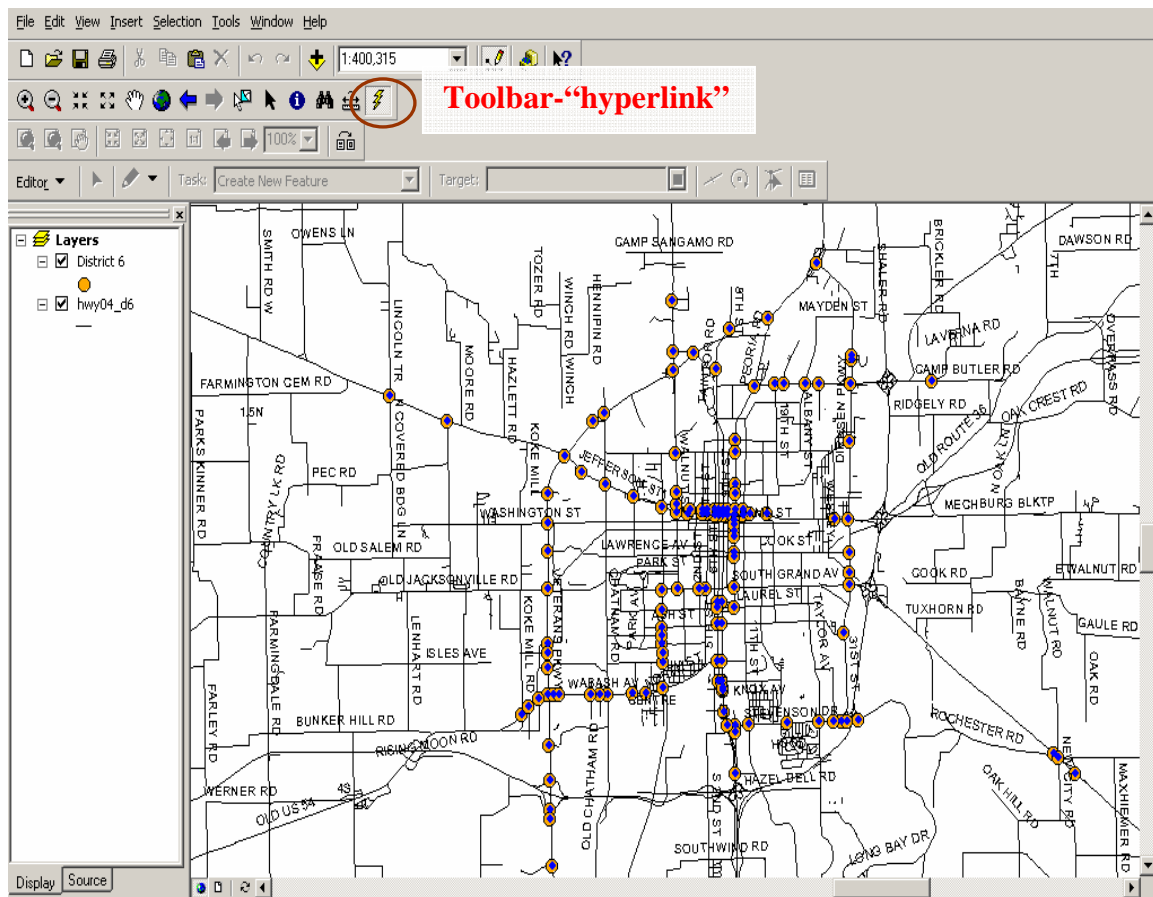

Figure 4.4 Intersections with Hyperlink

◈ Click the intersection that you want to look at. The associated video and image will appear in a window. For example, the window of the intersection of Jefferson and Bruns Lane is show below:

Figure 4.5 HTML page for Intersection of Jefferson and Bruns Lane

◆ Click the button of any approach (NB, SB, EB, and WB) to view the video or
image of that approach. For example, the following picture shows the east
bound of the intersection of Jefferson and Bruns Lane in the city of Springfield.

Figure 4.6 Picture of East Bound of Intersection of Jefferson and Bruns Lane

◆ If you would like to view the short video of any approach of the selected

intersection, you can click on the approach button of Video. For example, you

can play and replay the short video of the north bound approach of the selected

intersection by clicking the play button in Media Player Window.

Figure 4.7 Video for North Bound of Intersection of Jefferson and Bruns Lane

4.2.2. How to Query Relevant Information on Traffic Signals.

Using Query Builder in ArcMap, click the "Selection" menu and choose "Select by Attributes". To build the query, double click on the fields, buttons and values or build your own query by typing in the box. Click on "Apply" when you are done. You can save these   selections as a new shapefile. Right-click on the layer and choose Data then Export Data.

Some query examples are shown below:

Query Example 1. All intersections with EAGLE Signal Cabinet in city of Springfield were highlighted as light blue color and circled in Fig 4.8:
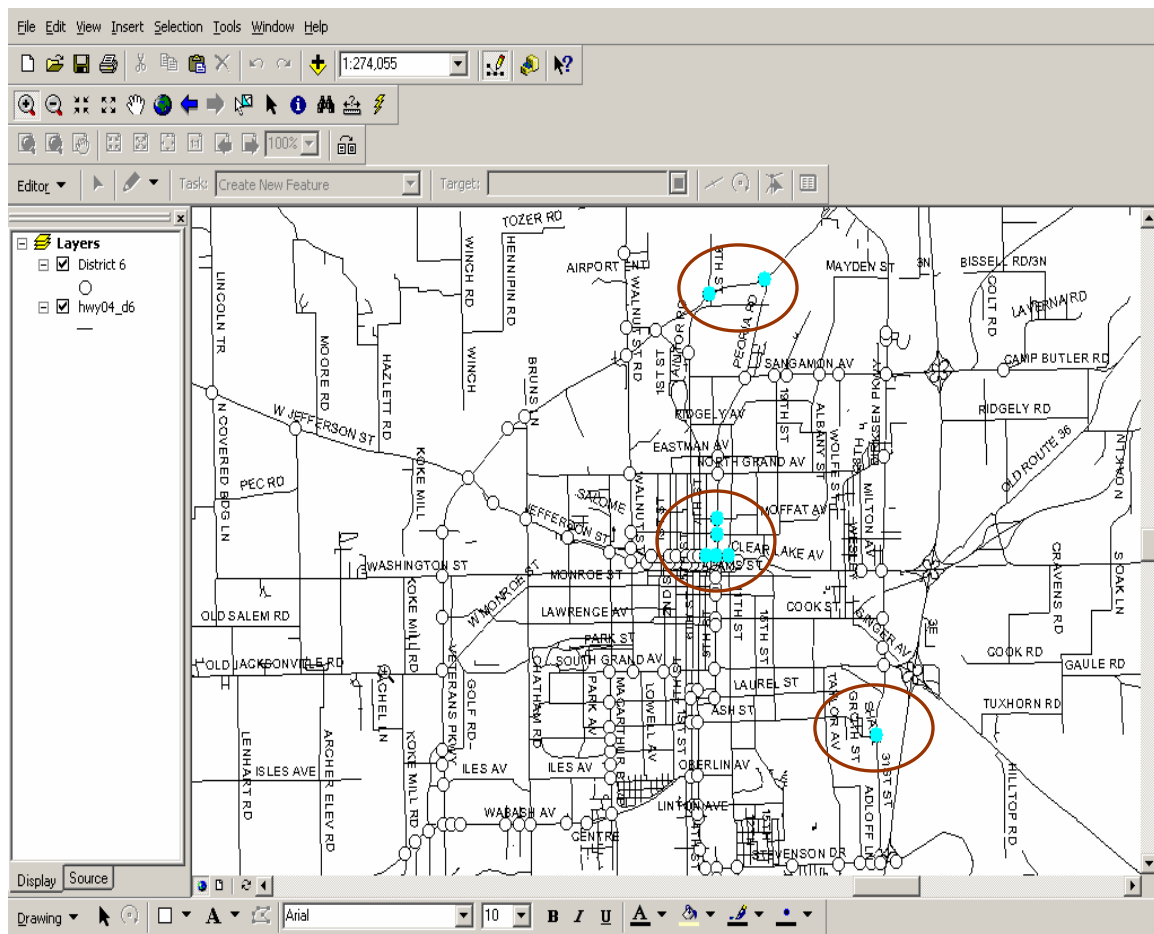

Figure 4.8 Intersections with Eagle Signal Cabinet in Springfield

Query Example 2. All intersections with ECON TS2-TY2 Signal Cabinet in city of

Springfield were highlighted as light blue color and circled in Fig. 4.9:
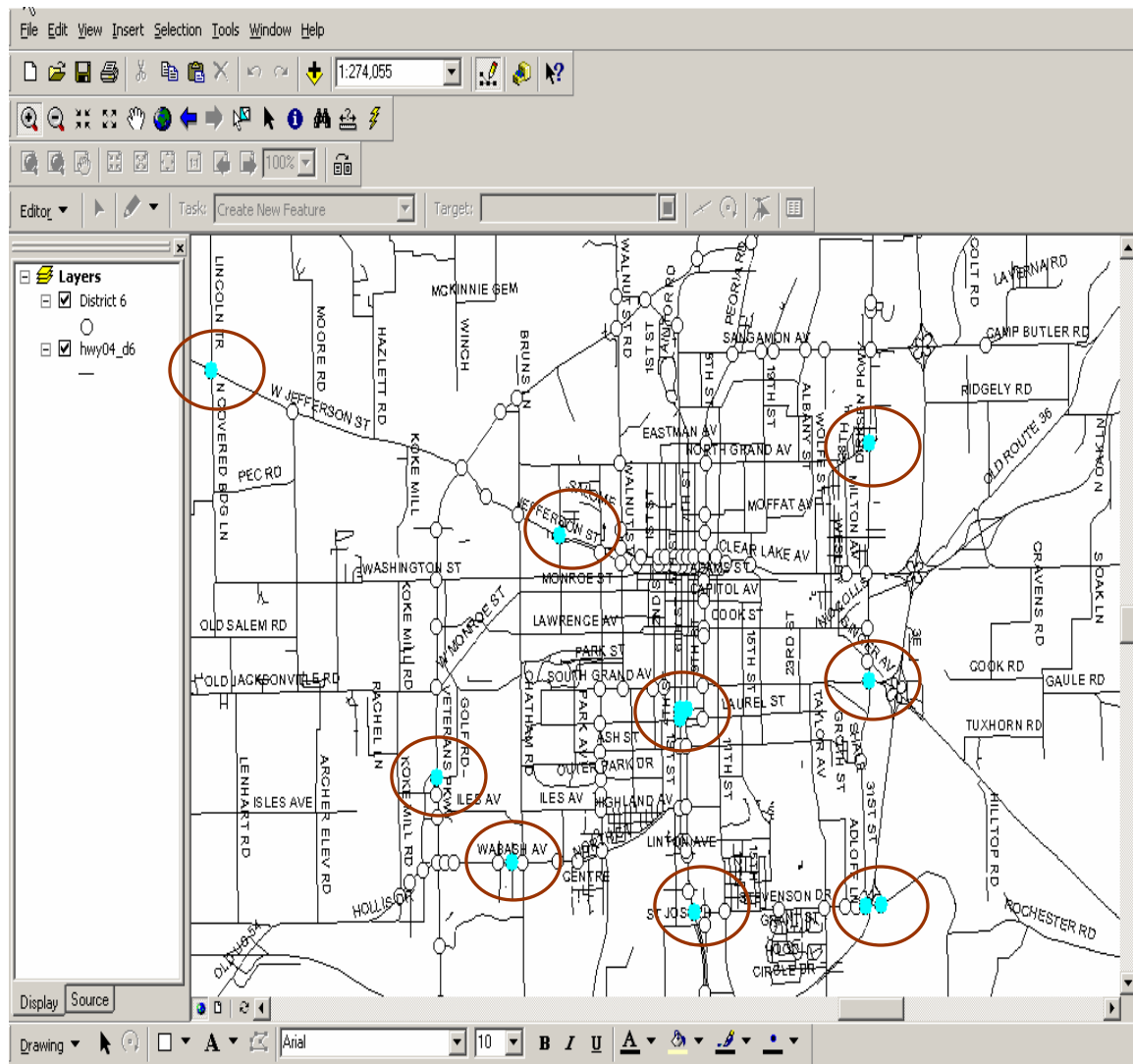

Figure 4.9 Intersections with ECON TS2-TY2 Cabinet in Springfield

Query Example 3. All intersections with 2004 LE Video Detector in city of Springfield

were highlighted as light blue color and circled in Fig 4.10:

Figure 4.10 Intersections with 2004LE Video Detector in Springfield

5. Conclusion and Recommendation

This study developed a GIS based Intersection Inventory System for the signalized intersections on the state-maintained highway system of IDOT District 6. Efficient field data collection and data processing procedures were developed along with a process for integrating multimedia and other traffic signal information into the GIS framework. GIS-IIS provides a tool to give easy access to intersection inventory system, photographs and videos of each approach as well as an ability to query the information. To help in understanding the use of GIS-IIS, the research team also created a demonstration CD to show some applications of GIS-IIS.

It is recommended to develop a statewide intersection inventory system. In the future, updated GIS maps with information on both local street name and highway route number should be used to save the time spent on digitizing intersections. In addition, the the methods of expanding GIS-IIS to create a comprehensive information system by incorporating more information, such as traffic and geometric information, construction and maintenance information, and intersection accident database, should be studied.

## Appendix A- Updating Images or Attributes of Existing Intersections

◆ **Updating Video and Pictures**

Each intersection has one subfolder in the folder "GIS Html" that has the video and image files. The users can replace the old files with the new files. For example, to update the short video of the south bound approach of intersection of Dirksen and Sangamon, save the new video file as "Dirksen-Sangamon-SB.mpg", and put the file into the folder of "C:\GIS trafficlight\GIS Html\Dirksen-Sangamon " to replace the old file with the same name.
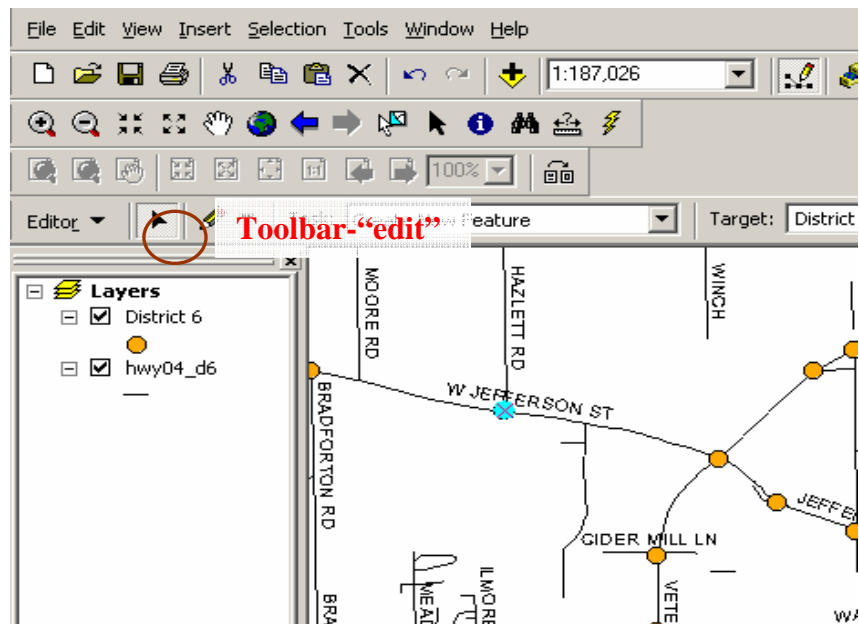
◆ **Updating other attributes**

The procedure to update other attributes using ArcMAP user interface is shown below:

1. Open GIS-IIS program

2. Click on toolbar "Editor", then click "Start Editing" and select the folder/database to be modified as "traffic-light-data-base"
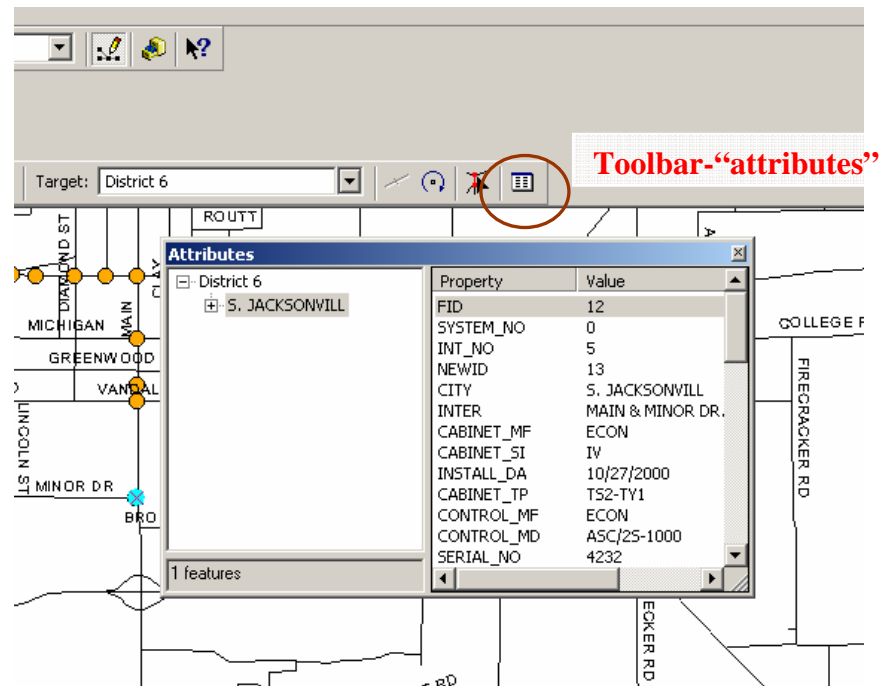
Toolbar - "Editor"

Specify "traffic_light_data_base" to be edited
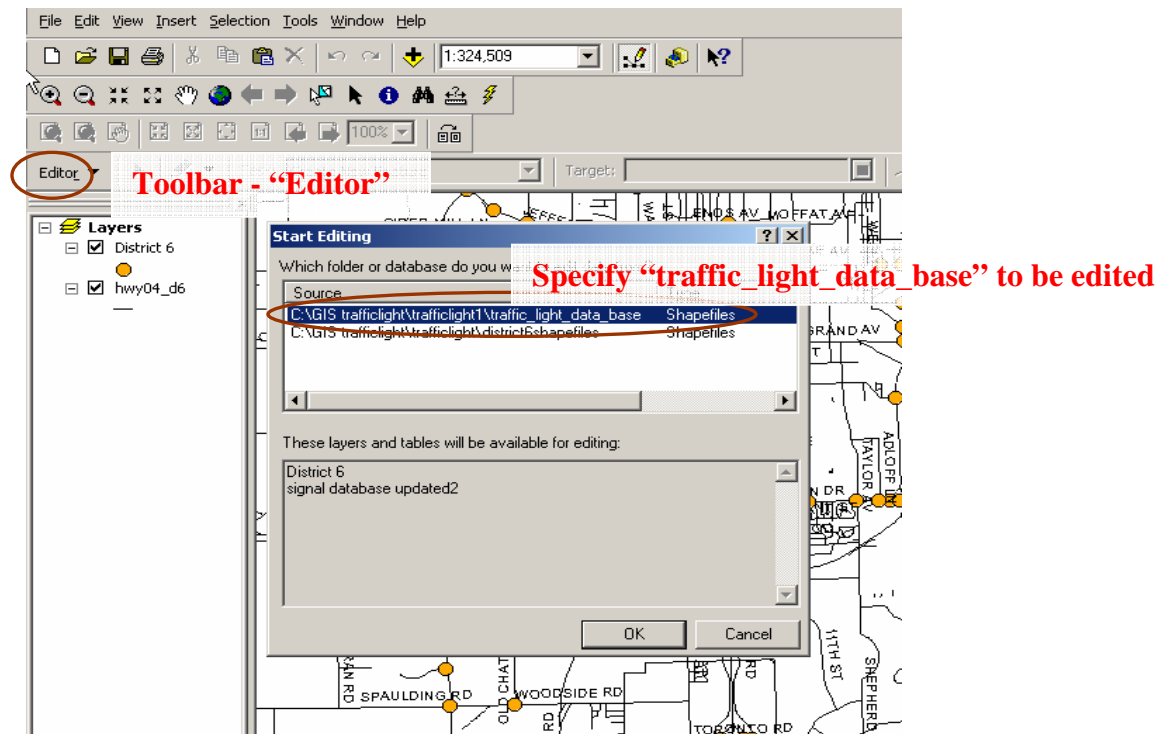
3. Click on toolbar "Editor/edit", and then click on the intersection you want to
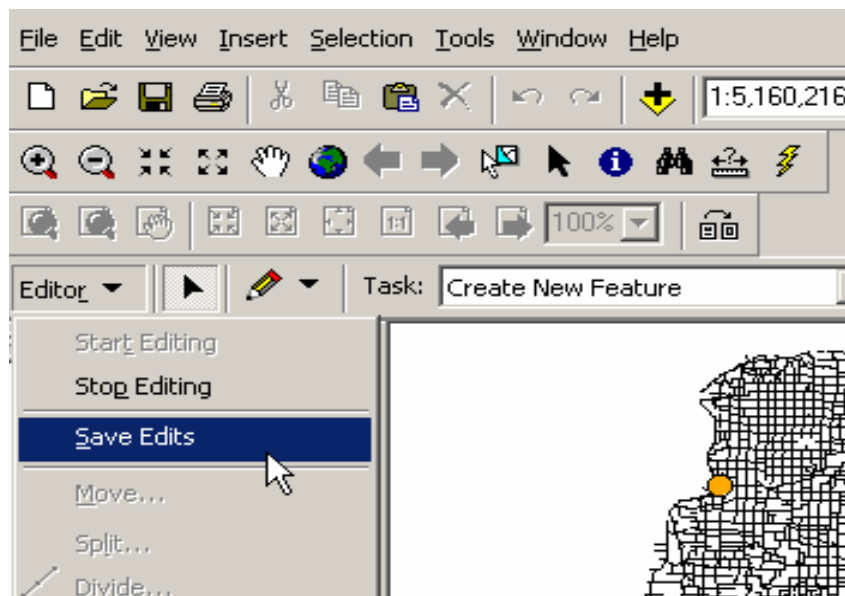   update to highlight it.

Toolbar-"edit"

4. Click on toolbar "Attributes" to update the information in the attribute editing box.
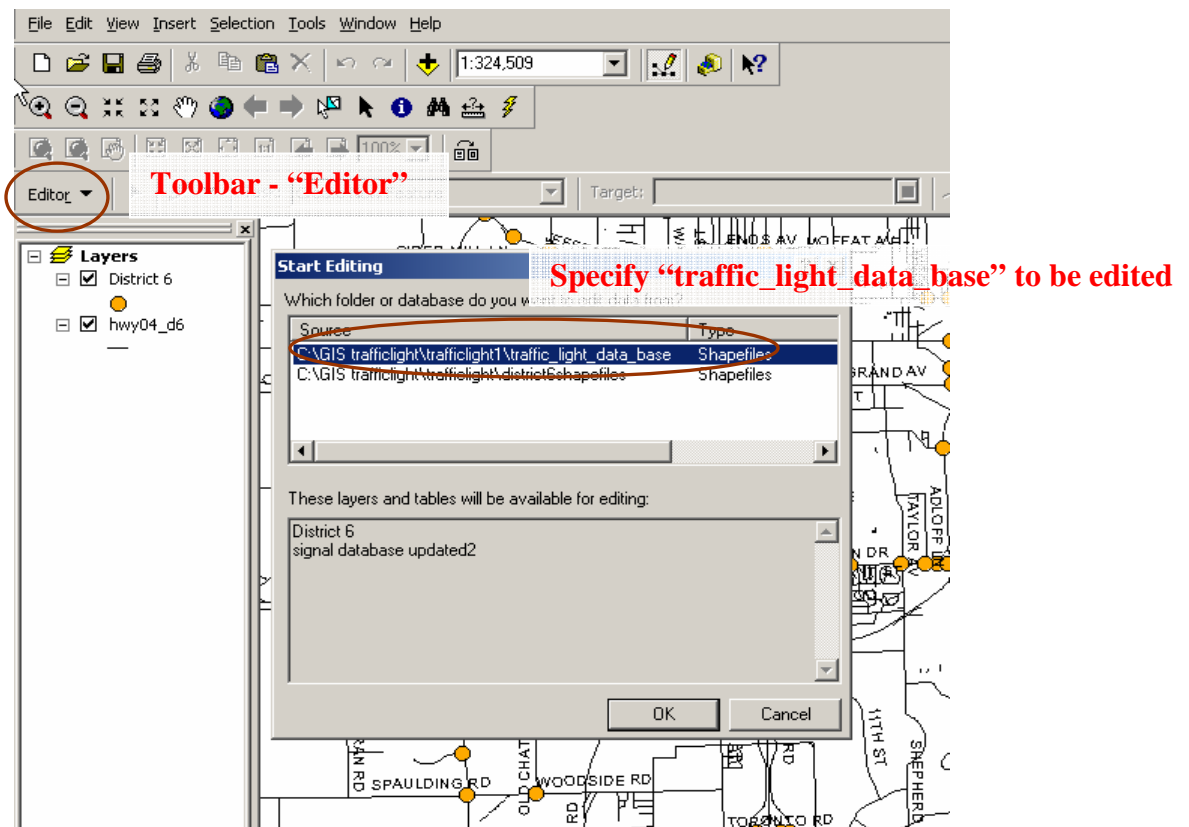
   After updating the information, close the editing box.

5. Then click on toolbar "Edit-Save Edits" to save the changes. Then close the GIS-IIS program and save your change to the project.

Appendix B- Adding a New Intersection

The information about newly constructed or upgraded intersections needs to be added to the GIS-IIS system. The new intersection does not exist in the current GIS database, so the first step is to create a feature on the intersection layer. The procedure to add a new intersection using ArcMAP user interface is shown below:
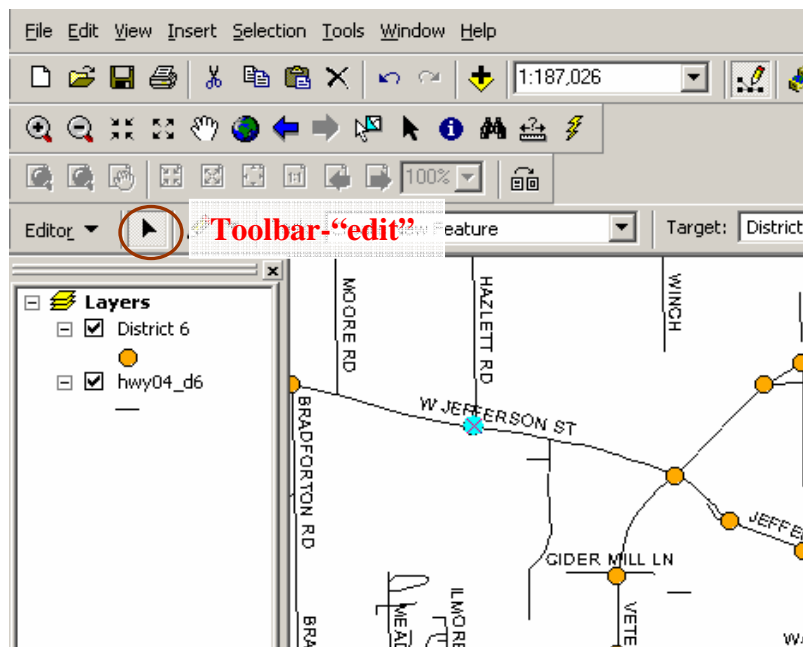
1. Open GIS-IIS program

2. Click on toolbar "Editor", then click "Start Editing" and select the folder/database to be modified as "traffic-light-data-base"

3. Click on toolbar "Create New Feature", and then click on the intersection you want to add to digitize it on the map.
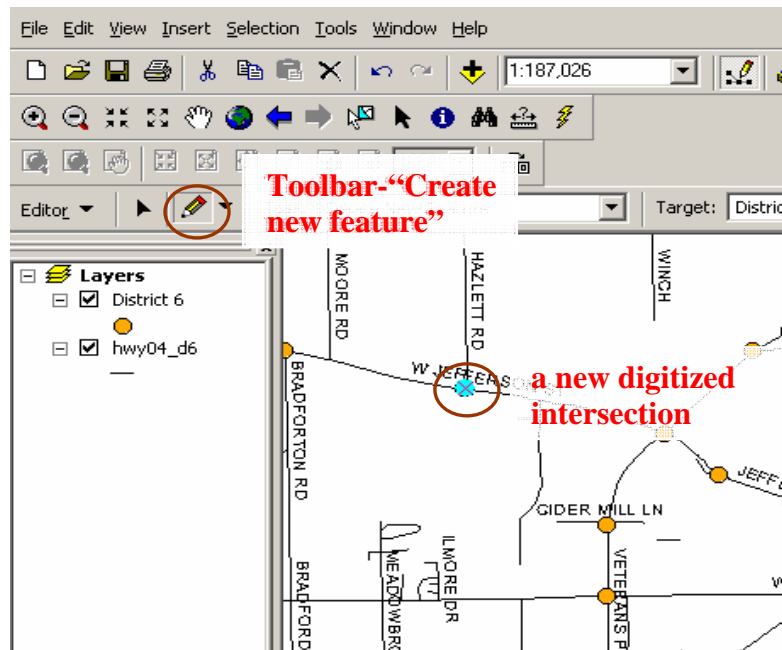

4. Click on toolbar "Editor/edit", and then click on the intersection you want to add/update to highlight it.

5. Click on toolbar "Attributes" to update the information in the attribute editing box.
    After updating the information, close the editing box. Then click on toolbar "Edit-
    Save Edits" to save the changes. Then close the GIS-IIS program and save your
    change to the project.
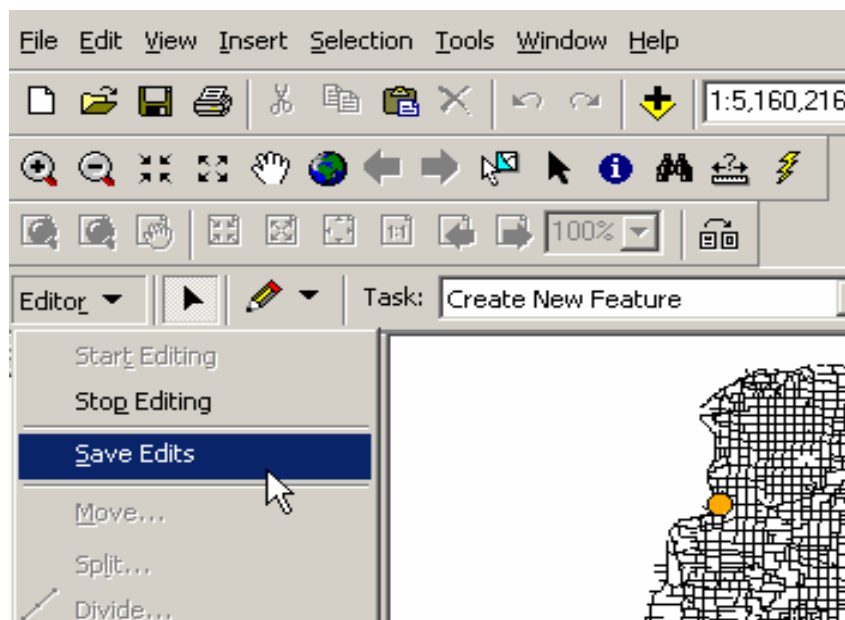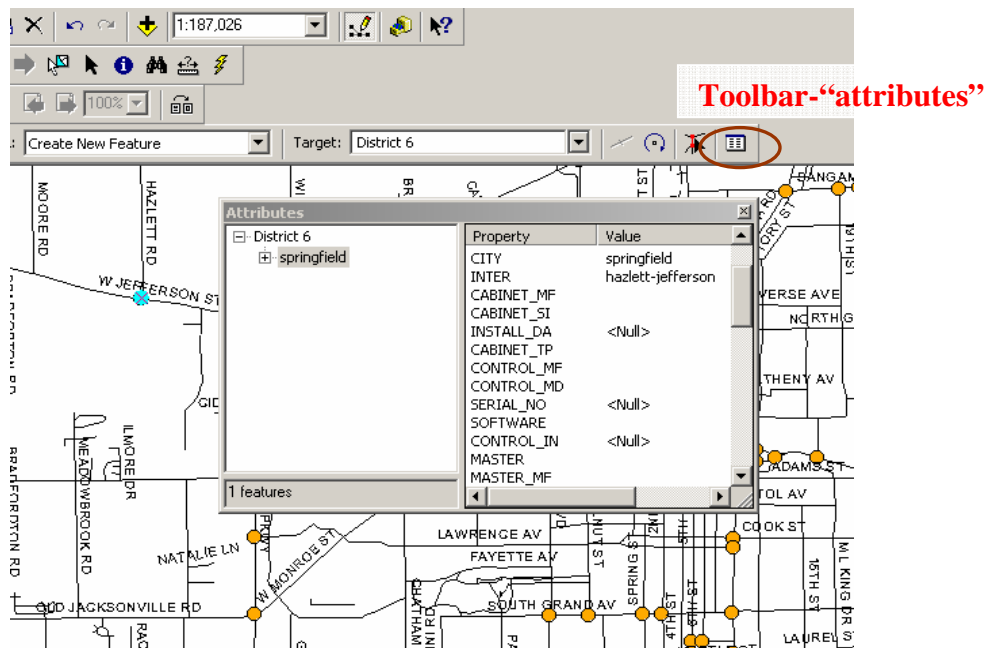
6. To add intersection images, follow step 4 to highlight the intersection and step 5 to open the editing box. For example, a new intersection "Jefferson-Hazlett" is digitized.

A. Input "Jefferson-Hazlett.htm" to IMAGE attribute in the attribute editing box, and save your change.

B. Then create a new folder "Jefferson-Hazlett" in C:\GIS trafficlight\GIS Html. Put the intersection images in this folder. All new video and image files for the new intersection "Jefferson-Hazlett" need to be named following the current format, for example save the north bound picture as "Jefferson-Hazlett-NB.jpg" and north bound video file as "Jefferson-Hazlett-NB.mpg". Also, you need to create 5 htm files in this folder. A short way to do this is copying these files from another intersection and modifying the contents. For example, go to C:\GIS trafficlight\GIS Html and choose, say, "9-South Grand". Then copy the following 5 htm files to the new folder:

> C:\GIS trafficlight\GIS Html\ 9-South Grand \title.htm
>
> C:\GIS trafficlight\GIS Html\ 9-South Grand \ 9-South Grand -EB.htm
>
> C:\GIS trafficlight\GIS Html\ 9-South Grand \ 9-South Grand -WB.htm
>
> C:\GIS trafficlight\GIS Html\ 9-South Grand \ 9-South Grand -NB.htm
>
> C:\GIS trafficlight\GIS Html\ 9-South Grand \ 9-South Grand -SB.htm

C. Then rename each of these 5 files to show the name of the new intersection. Then open each file and replace the old intersection name with the new one. Save each of them and close the folder. For example, all places to be modified are highlighted in one of the files:

```
1   <HTML>
2   <HEAD>
3   <TITLE>Video</TITLE>
4   <META NAME="Generator" CONTENT="EditPlus">
5   <META NAME="Author" CONTENT="">
6   <META NAME="Keywords" CONTENT="">
7   <META NAME="Description" CONTENT="">
8   </HEAD>
9
10  <BODY>
11  <center>
12  <object id="MediaPlayer" width="480" height="400"
13    classid="CLSID:22d6f312-b0f6-11d0-94ab-0080c74c7e95"
14    codebase="http://activex.microsoft.com/activex/controls/mplayer/en/nsmp2inf.cab#Version=6,4,5,715"
15    standby="Loading Microsoft Windows Media Player components..."
16    type="application/x-oleobject">
17
18      <param name="FileName" value="9-South Grand-EB.mpg">
19      <param name="AnimationatStart" value="true">
20      <param name="TransparentatStart" value="false">
21      <param name="AutoStart" value="true">
22      <param name="ShowControls" value="1">
23
24      <embed type="application/x-mplayer2"
25        pluginspage="http://www.microsoft.com/isapi/redir.dll?prd=windows&sbp=mediaplayer&ar=Media&sba=Plugin&"
26        src="9-South Grand-EB.mpg"
27        name="MediaPlayer"
28        ShowControls="1"
29        width="480"
30        height="360"
31        >
32      </embed>
33  </object>
34  </center>
35  <p> </p>
36  </BODY>
37  </HTML>
```

D. Go to C:\GIS trafficlight\GIS Html and make a copy of 9-South Grand.htm file, and rename it to new intersection, for example Jefferson-Hazlett.htm. Open this file and replace the old intersection name with the new intersection name. Save the file.

34