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## Applications of GIS for Bridges Maintenance Service

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# Applications of GIS for Bridges Maintenance Service

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**Abstract.** AThe Bridge Maintenance Management System (BMMS) is an application system that uses existing data from a Bridge Management System database for monitoring and analysis of current bridges performance, as well as for estimating the current and future maintenance and rehabilitation needs of the bridges. In a transportation context, the maintenance management is described as a cost-effective process to operate, construct, and maintain physical money. This needs analytical tools to support the allocation of resources, materials, equipment, including personnel, and supplies. Therefore, Geographic Information System (GIS) can be considered as one tool to develop the road and bridge maintenance management system.

This research aims to use GIS to create a database for bridge maintenance system. Two study areas have been chosen: the old construction bridge (Al-Qadisiyah) and the newly constructed bridge (Barboty). Both of them are in Al-Muthanna city\Iraq. The creation of database was based on field surveying data. In order to monitor the damages and decline of the bridges, four periodically observations have been achieved. The first analysis of the observations was conducted by graphical analysis which gave the results between all the observations. The second part of analysis included the process of documenting the cracks observed in both study areas via hyperlink tool. This tool can display each of the bridge cracks in the form of window that contains full information for each crack such as, photo of the crack, station number of the crack, coordinates of the crack, type of crack, the crack description, and risk levels of the crack. This information may help to save cost, time and effort to decision makers in the relevant institutions.

## 1. Introduction

Geographic Information System (GIS) is a system for plotting and investigating features on the Earth. It is a way to collect, store and manage any type of data with geospatial components. GIS data is typically stored in further than one layer. This is the basic aspect of GIS, working with layers of geographic information commonly known as data incorporation. This makes the GIS unique among the various data collection systems. Fundamentally, this system has the ability to overlap with the map and provide an information query facility that can ramblingly generate a whole new set of communication. At this point, data can be obtained in the form of tables, maps, graphs or a combination of these three. The other strong side of the GIS is its flexibility in modeling spatial objects to suit the particular needs of the user or application. The GIS offers a set of instruments or computer packages that allow the user to perform a specific operation on the map, with the help of a set of attribute data [1]. Therefore, GIS can be used to develop road and bridge maintenance management system. In a transportation context, the maintenance management is described as a cost-effective process



to operate, construct, and maintain physical money. This needs analytical tools to support the allocation of resources, materials, equipment, including personnel, and supplies.

Bridges are a capability consisting of the means and equipment that are necessary for the movement of passengers or goods, and it is a means of transporting staff, students and employers etc. Bridges are also considered to be the best way to reduce congestion in the city [2]. Damage to bridges or lower passageways can be classified as: damage to the concrete walls, damage to the lower parts of the concrete bridges, damage to the concrete by the rust of the reinforcing steel, damage to the chairs, damage to the concrete from iron rust, damage to collisions with high trucks, damage to expansion joints of bridges etc., and the most significant damage is the passage of heavy duty vehicles carrying more than the specified weight [3]. The causes of these damages are due to several reasons, including:

- Absence of supervision and follow-up and weak penalties applied to violators.
- These bridges are located in the city centers or important transit areas, leading to the crossing of many vehicles on them.
- Ease of granting licenses and may be followed by non-specialized sectors.
- Lack of GIS applications in road management facilities and the mechanism of distribution and licensing of restrooms and stations based on data, also geographical areas such as village areas, lengths of roads, places of paintings, sites of gas stations and other statistics such as the density of pedestrians, information restrooms and others.

Geographic Information System (GIS) can be considered as a tool that can be used to develop bridge maintenance management for its ability to represent, process, and analyze all types of bricks on earth using spatial components. GIS data can be usually used to aggregate data in more of a single layer called "shapefile or feature class." These layers can also be combined with other layers of geographic information in a process called data integration. This makes unique GIS between different information gathering systems [4]. Following are some of previous researches which related to the topic of this research.

[5] Illustrated that the roads networks in India are enormous with in excess of 3.01 million kilometer of roads lengths with 34608 km of Nationalized Roads, 128622 km of State Roads and unofficial networks of 2737080 km, managed in immensely dissimilar social, economic, and climatic surroundings. The maintenance management of the enormous networks in the India was principally done at two types of levels: local and national level. The first level is problem particular and limited to a few municipal capital cities, while the second level in the India is comprehensive grounded and is done utilizing some macro level data such as area, uncultured national products etc. The main management in diverse phases of roads networks can be obtained to the absence of obtainability of huge capacity of data obligatory. At the time, no organization can use this information for the adequacy of the network in the regional context or to produce a large-scale scheme for the primary network such as highways and major roads. Therefore, the observable data obtained in a large number of locations in all possible formats is not useful, and the sources spent on collecting and maintaining such data drain the economy as a non-useful regular and do not achieve the desired aims. The main objectives of GIS use are data integration and map / display. The main aim of this research is to reveal the role of GIS technology in the enhancement of bridge maintenance management system components such as the output results through creating a comprehensive database (Geodatabase) for both study areas.

[1] Stated that the development and economic increase of a nation is closely associated to its accessible transportation system. Efficient road transport infrastructure capabilities will promote industrial and socio-economic development. To deliver security and comfort to road users, a comprehensive road maintenance agenda must be formulated and assumed to safeguard those roads are in good condition at all times. Preventive maintenance works, like road rehabilitation will assist to decrease the main road repairs and expenditure. Previous to this, a suitable database, collected through GIS will be necessitous. The GIS is one of the effective tools that can be used to manage database in road maintenance engineering.

[6] Showed the relation among the Web-GIS and remote sensing as tools to bridge maintenance management system BMMS. GIS-Based TRIMS offer a mechanism for data integration, management, development, and production generation in its spatial environment. The objective of this study is to develop a GIS-Based roads transportation information maintenance management system for Adamawa Central. In order to realize the objective and aims of this study, Satellite image, roads transport maps, roads transportation brochures, picture of; bridges roundabout and their coordinates were obtained. The road transport infrastructures were mapped utilizing the satellite imageries. File geodatabase was generated in ArcCatalog. The appearance dataset was populated utilizing the road transport documents that served as an inventory of the dataset and the database was lastly generated. RTIMS was built by means of ArcGIS 10.1. Query analysis was transmitted out on the results. The paper disclosed that the federal road covered 7.94% length, state road 22.27% while the LGA road was the longest of (77.73%). It also discloses that 78% of the LG roads were untarred while only 22% were tarred, the tarred roads were typically localized in the Yola north which is the state capital. It also there were twelve roundabouts in the study area and three of them were under construction. Also, there were six bridges in the area, with (Gerei LGA) having two with one under structure.

## **2. Study Areas**

Two study areas have been chosen: Al-Qadisiyah bridge and Barboty bridge. The reason behind this choice is the importance of these bridges for the Samawa city, in addition they are affected by the heavy loads, precipitation in soil, rain water, and cracks.

### *2.1. Al-Qadisiyah Bridge*

Al-Qadisiyah bridge is located in the southwest part of Samawa city. It is connecting the city center with Najaf city and it is passing over Al-Qadisiyah river which is one of Euphrates river branches. This bridge also leads to Salman town which is located near Saudi Arabia kingdom's borders. The bridge laying between (523522.786m E, 3458868.649m N) and (523677.602m E, 3458995.62m N), (Directorate of Roads and Bridges in Al-Muthanna, 2018). Figure 1 represents a satellite image of Al-Qadisiyah bridge.

The total length of the bridge is 200 meters, 50 meters on each approach. The width of the bridge is 12 meters. What is worth mentioning is that this bridge is connecting between cement plants in Al-Muthanna province. Therefore, most of vehicles passing through it are heavy loads trucks. These heavy trucks may cause cracks and geometric issues; thus, these issues will be investigated in this article.

### *2.2. Barboty Bridge*

Barboty bridge is located in the western part of Samawa city. It's one of the important bridges which is constructed recently. It's laying between (524266.642m E, 3465978.518m N) and (524277.446m E, 3465658.394m N). The length of Barboty bridge is 154 meters long without its approaches, and 319 meters long with its approaches. The width of the bridge is 13.76 meters. It contributed to reduce the traffic jam which is usually happening in the city center. This bridge is the longest one on the Euphrates, it's connecting Al-Rumaithaa city and Al-Warkaa city together alongside with Samawa city's entrance from the northern side, Directorate of Roads and Bridges in Muthanna, 2018. Figure 2 shows a satellite image for Barboty bridge.



**Figure 1.** Represents a satellite image of Al-Qadisiyah bridge (Sas.Planet software).

### 3. Data Collection

Data collection is an element of research in all fields of survey, counting social sciences and physical, business, and engineering as well. There are many methods which are depending on the tools or instruments (e.g. total station or level instrument) in which the data is collected. The focus on ensuring the accurate collection makes the results that are intended to reach it with high precision [7]. In this paper, the bridges have been divided into six layers in order to observe and compare different locations of points on the bodies of the bridges. These layers included: the side walk (s), fence (f), border (b), electricity (e), joints (j), and cracks (c). The meteorological process is repeated every 3 months, in 4 different annual seasons, to determine the variation in levels, the amount of settlement that occurs for each bridge and its causes and the possible solutions. There are two instruments have been used in this study: total station and level. The total station is Nikon-Nivo total station 5.C.  $5'' \pm (3\text{Mm} + 2\text{PPM})$ , and the level is Topcon AT-B4 which is a new standard to measure the elevations.

Al-Qadisiyah bridge (Q) was observed using total station to determine (Easting and Northing) coordinates and the level to determine (Elevation). The first three layers were observed are border, side walk, and fence layer. After that, the electricity pole layer which containing 21 columns for every side. Every electric pole was observed at the base of it. The joint layer was the last layer which was observed by 3 observations (left, right, and center). Finally, the cracks layer was observed at the centre for documentation purposes. All these cracks have been identified with its numbers and discretion.



**Figure 2.** Represents a satellite image for Barboty bridge (Directorate of Roads and Bridges in Al-Muthanna, 2018).

Barboty bridge (B) was also observed using the same instruments to determine (Easting, Northing and Elevation). The first three layers were observed are border, fence, and side walk. After that, the electric poles layer which containing 13 columns. Every electric pole was observed at the base of it. The joints layer was the last layer which was observed through 3 observations (left, right, and center). Finally, the cracks layer was observed at the centre for documentation purposes. All these cracks have been identified with its numbers and descriptions. Table 1 shows the time period, date, and the temperature of the observations period.

**Table 1.** Shows the time, date, and the temperature of the observations period.

Observation Number	Time of Observations	Date of Observations	Temperature of observations
<b>1<sup>st</sup> observation</b>	7:30 am - 11:30 am	3/11/2017 - 12/11/2017	26 C°
<b>2<sup>nd</sup> observation</b>	8:00 am - 12:30pm	5/2/2018 - 13/2/2018	14 C°
<b>3<sup>rd</sup> observation</b>	7:00 am - 11:30 am	3/5/2018 - 12/5/2018	35 C°
<b>4<sup>th</sup> observation</b>	6:00 am - 11:00 am	6/8/2018 - 15/8/2018	47 C°

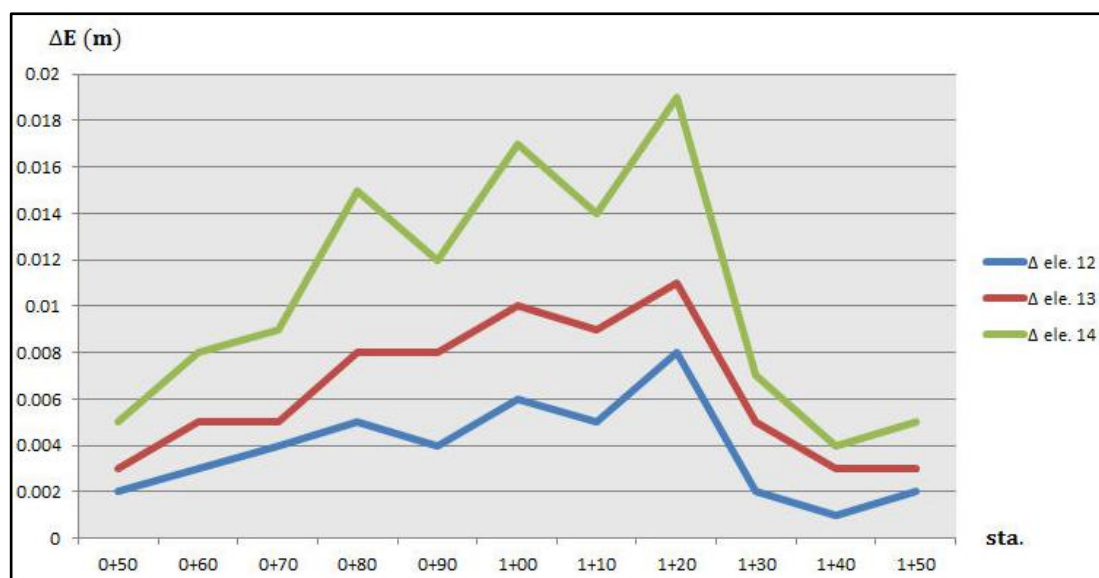
## 4. Results and Discussions

### 4.1. Results of Graphical Analysis

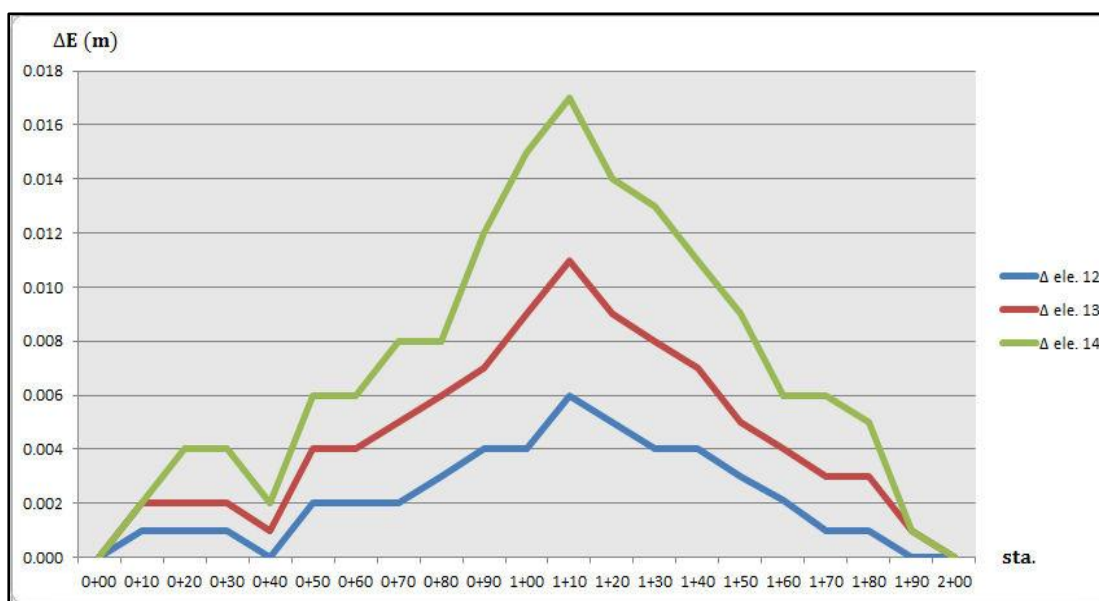
A graphical analysis is a tool for science researches to collect, draws, and analyze the collected data. It can be defined as the analyses of data to determine the optimal output. One of the powerful tools utilized for data valuation are the graphs. Utilizing graphical techniques can represent equations or tests of statistics and mathematics more easily and clearly [8]. The output of this research was presented as graphics as will be explained in the following sections.

#### 4.1.1. Results of Al-Qadisiyah Bridge

The graphical representation was applied to compare the differences between observations one, two, three, and four. The output of this analysis can be seen in figure 3 to figure 7.



**Figure 3.** Shows the differences between the observations of the border layer.



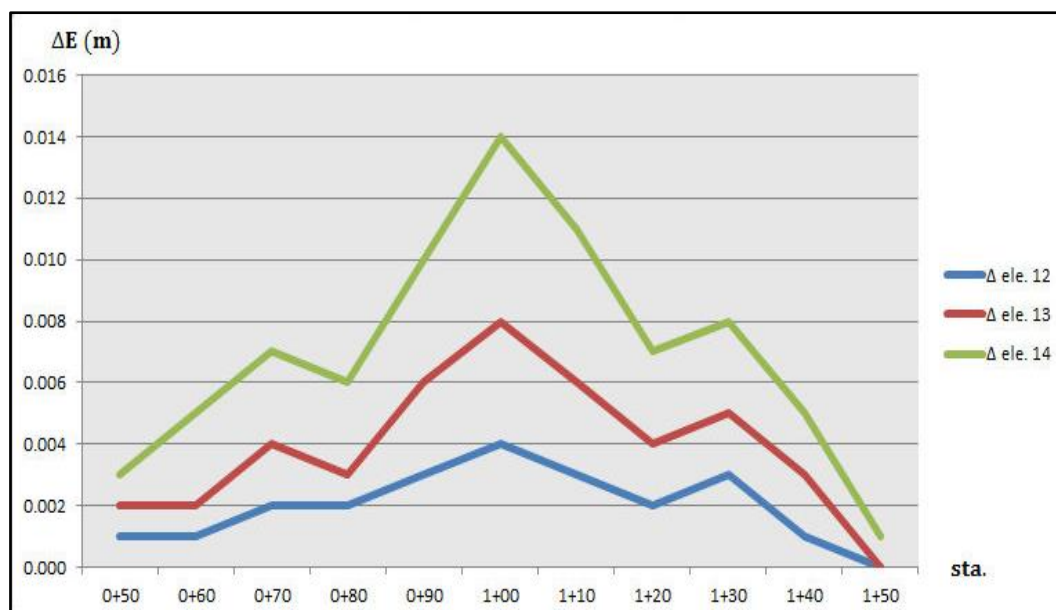
**Figure 4.** Shows the differences between the observations of the side walk layer.



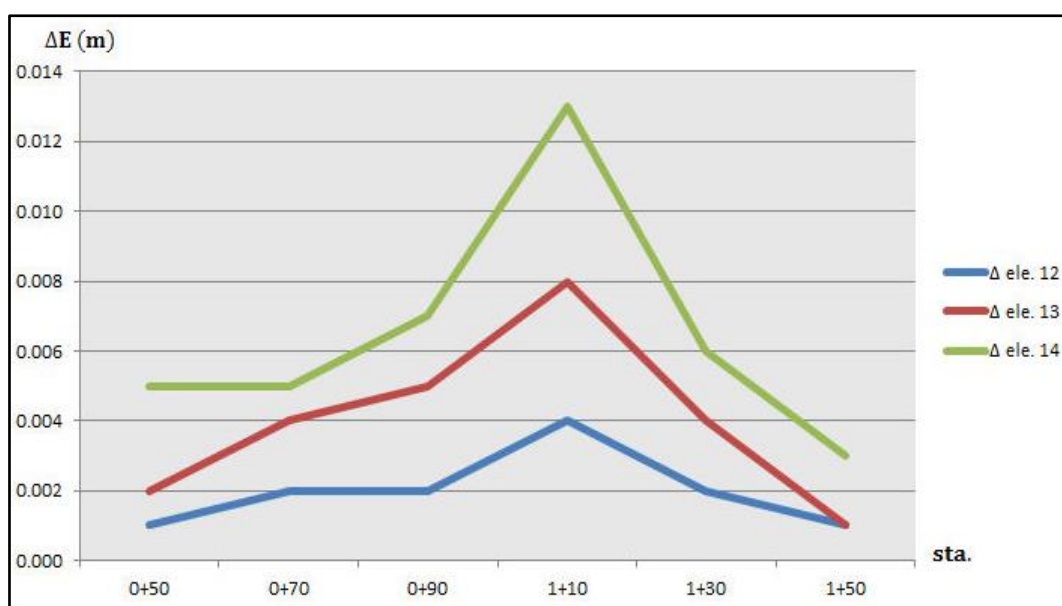
According to the graphs shown in figure 3 to figure 7, it is extremely clear that Al-Qadisiyah bridge suffers from very highly decline in the centre. This decline is about 19 mm in station (1+10). It can be also noticed that the least change value which is to be zero at the ends of the bridge. The concrete spaces of the bridge suffer from decline which is about 8 mm at the aspects of the bridge. The joint layer is the most important layer of the bridge because it is the only one capable of connecting the bridge spaces. The decline in this layer has been observed at the centre of the bridge which was found 16 mm. This may be causing a strong defect in the structure of the bridge.

#### 4.1.2. Results of Barboty Bridge

The differences between observations one, two, three, and four of Barboty Bridge have been also presented graphically. The output of this analysis can be seen in figure 8 to figure 12.

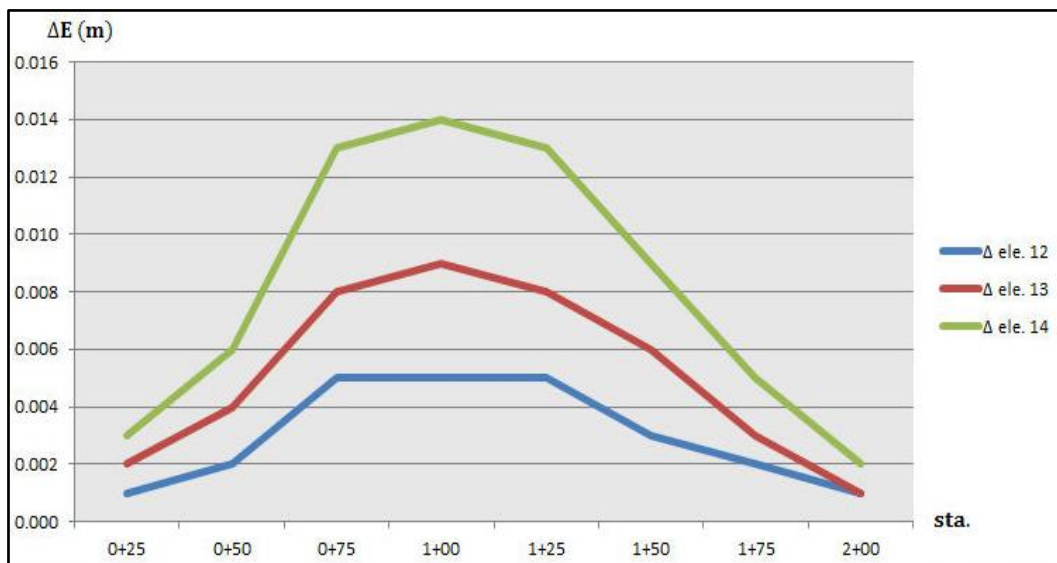


**Figure 5.** Shows differences between the observations of the fence layer.

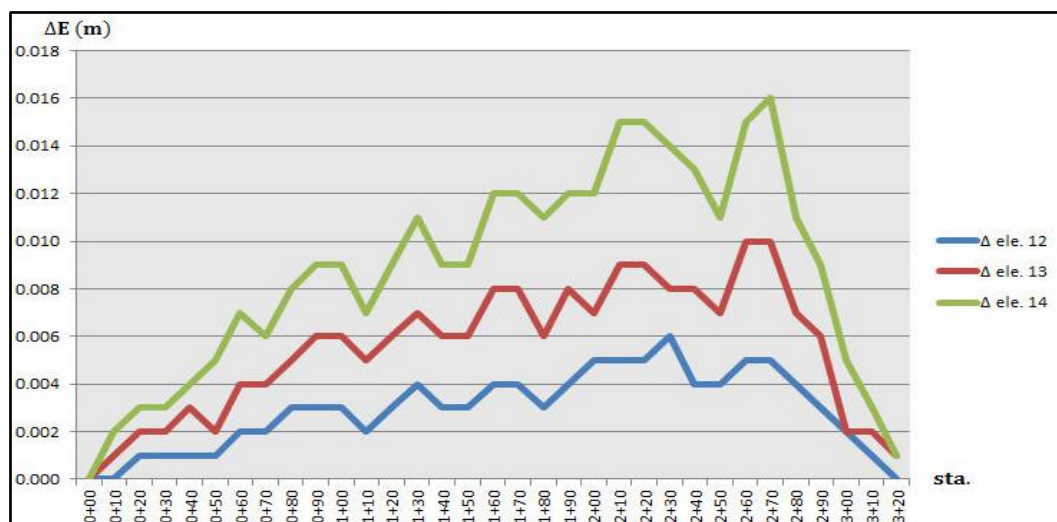


**Figure 6.** Shows the differences between the observations of the joints layer.

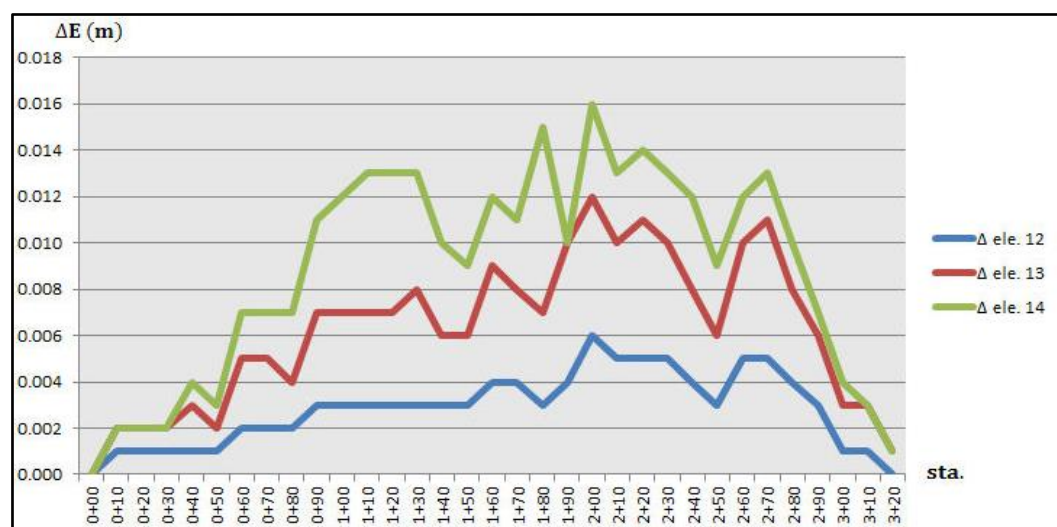




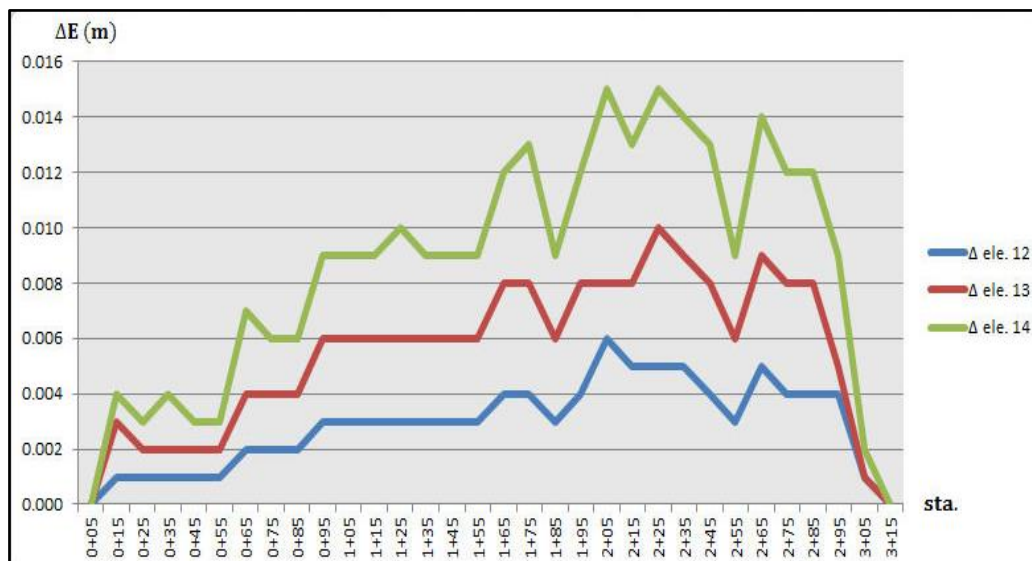
**Figure 7.** Shows the differences between the observations of the electric poles layer.



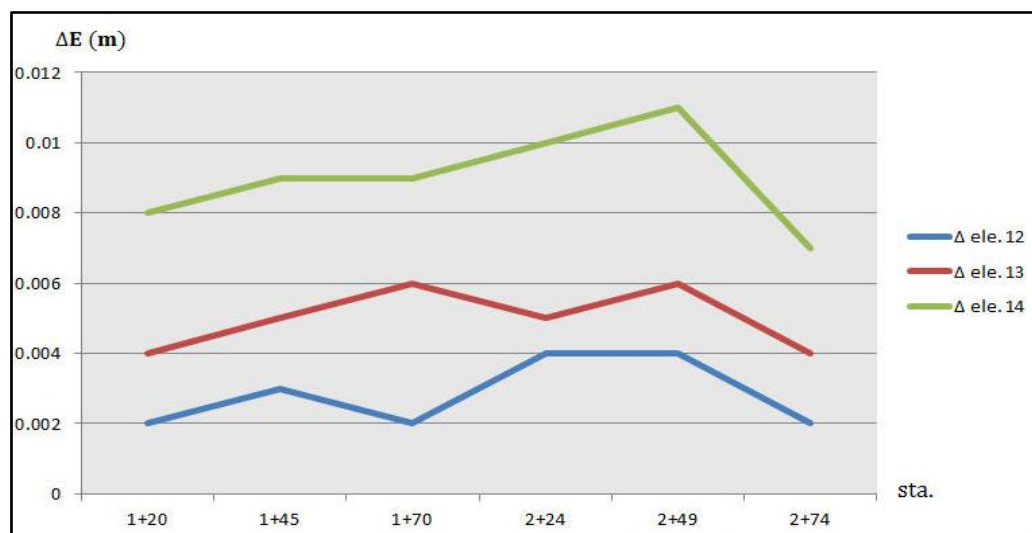
**Figure 8.** Shows the differences between the observations of the border layer.



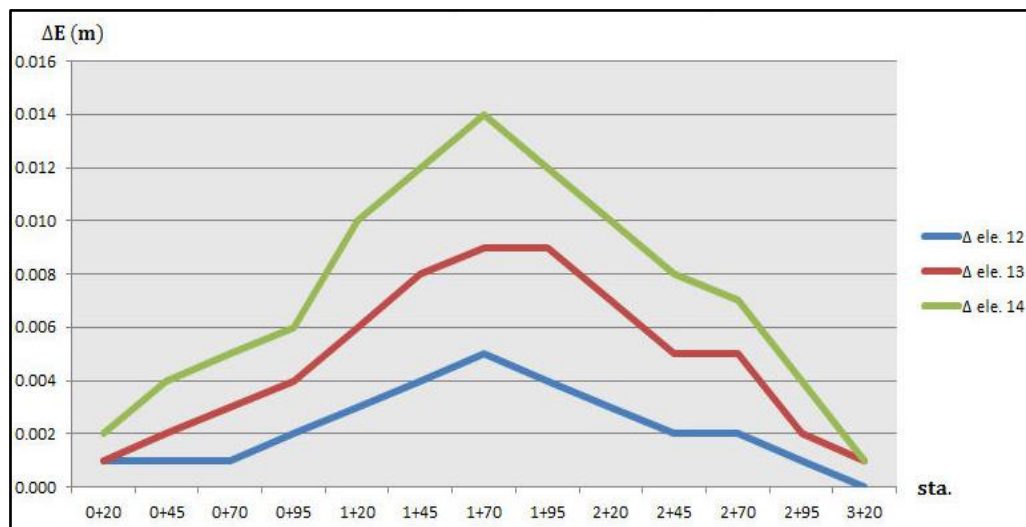
**Figure 9.** Shows the differences between the observations of the side walk layer.



**Figure 10.** Shows the differences between the observations of the fence layer.



**Figure 11.** Shows the differences between the observations of the joints layer.



**Figure 12.** Shows the differences between the observations of the electric poles layer.

According to the graphs shown in figure 8 to figure 12, it is extremely clear that Barboty bridge suffers from very highly decline in the steel space which is equal to 16 mm at station (2+00) in the side walk layer. In the last observation, it reached to the highest change in the decline which is equal to 18 mm. However, this girder extends from station (1+70) to (2+24). The decline in the elevation at every concrete space is 2 to 3 mm in the second observation, and it doesn't exceed 6 mm in the third observation, while the last observation showed decline 8 mm. The decline in the elevation of the northern and southern approaches of the bridge was 1 to 2 mm. That's expected because it is linked to the soil and it is low elevation compared with the structure of the bridge.

#### 4.2. Outputs of Hyperlink Tool for both Study Areas

Hyperlink tool is the item in a document or electronic document that leads to another section of the same document, or to a specific section of another document. It's mainly files location pointers that allow to the users to access related objects through specific actions (e.g. clicking on geographical features with a hyperlink). The hyperlink features of a GIS allow users to access numerous types of qualitative information related with particular geographical features in a GIS. Furthermore, numerous actions can be started through hyperlinks, such as a web page can be began in the default web browser through a universal resource locator (URL) [9]. In this study, the hyperlink tool has been adopted as a process of documenting additional information in spatial layers that have saved in database. This included information about cracks located in the study areas such as cracks style, their images, and coordinates. Once clicking on the hyperlink tool and go to any certain crack, full information will appear such as the coordinates of the crack and the station number of it. Also, a photo shows the crack type and its description such as lowest, normal, and the most dangerous level of this crack. This process is very important for the bridges to management and maintenance. The following figures illustrate some of the results of cracks which observed for both study areas:

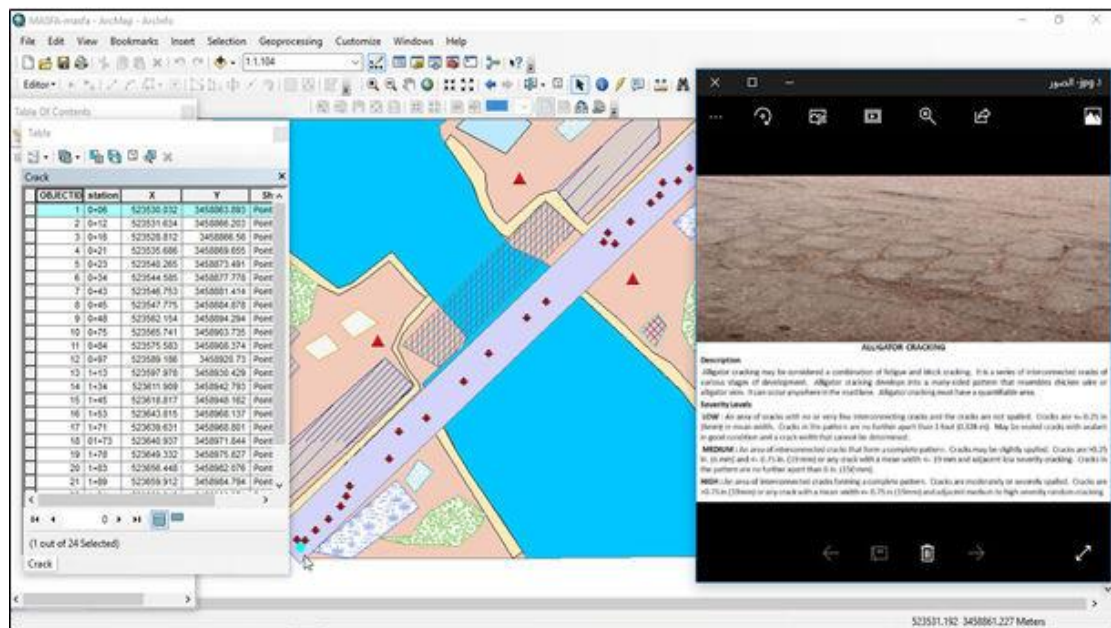


Figure 13. Shows the hyperlink output to the alligator crack of Al-Qadisiyah bridge.

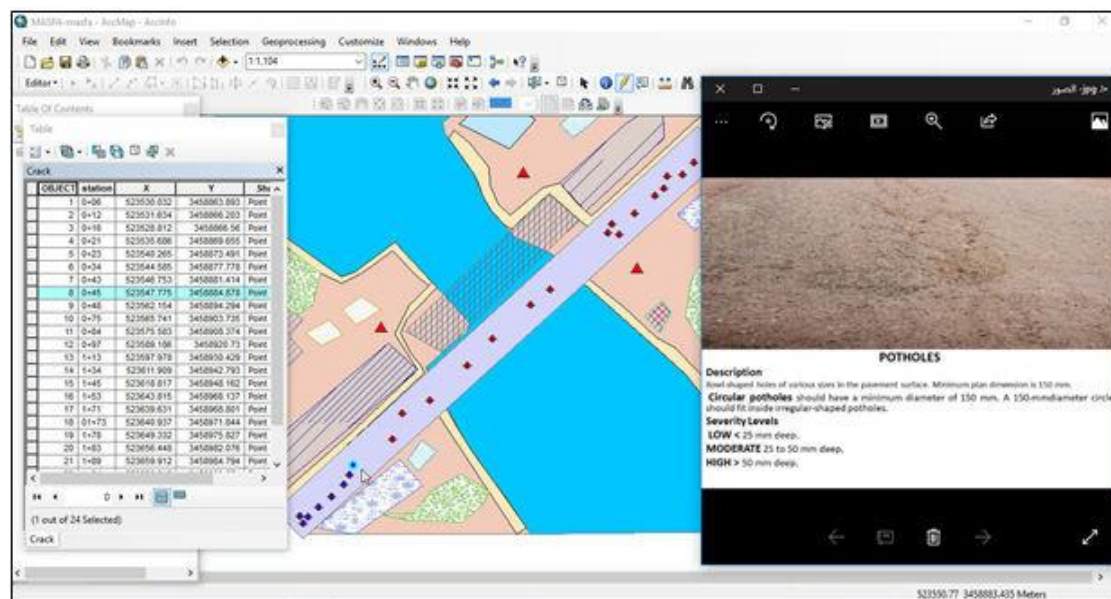
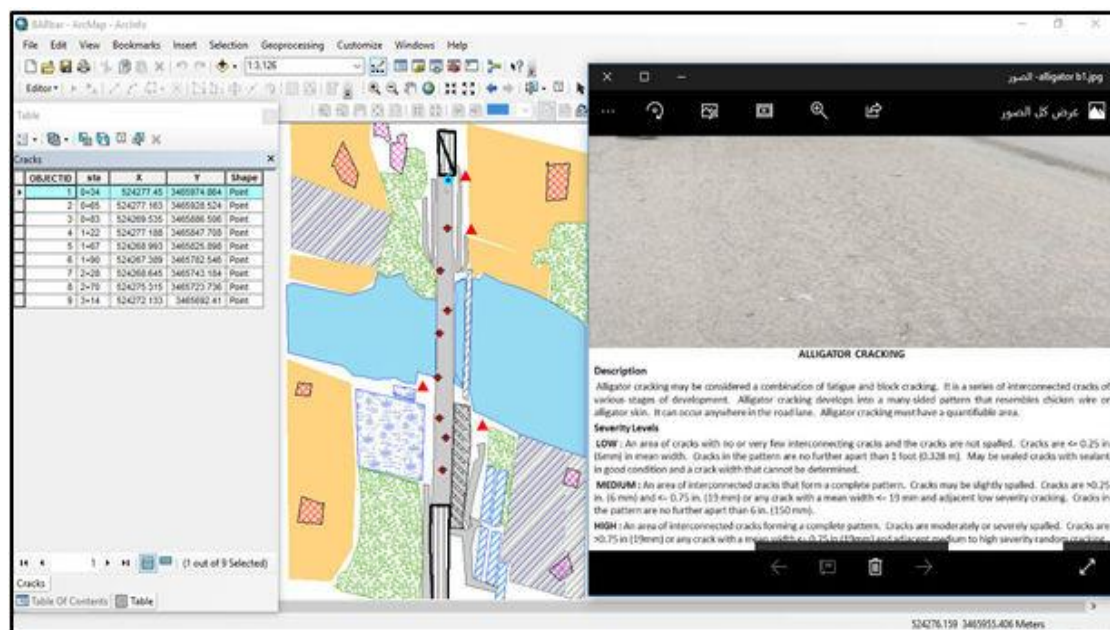


Figure 14. Shows the hyperlink output to the potholes crack of Al-Qadisiyah bridge.





**Figure 15.** Shows the hyperlink output to the alligator crack of Barboty bridge.

Hyperlink tool has been adopted to document the information of the cracks of the bridges for two study areas. By making the structure themes active, the hyperlink tool is utilized, the selected crack in green pops out an image of the discretion of the crack above by clicking it out. This analysis was achieved to display a physical nature of the crack for decision making in terms of maintenance and to see whether the crack is due for maintenance. And these are the pictorial representation of the bridge's cracks. Therefore, there is no requirement of physical site visitation or inspection. Most of the cracks that obtained at Al-Qadisiyah bridge are: alligator, transverse, longitudinal, potholes, rutting, block, and reflection cracking at joints. In contrast, the cracks that obtained at the Barboty bridge are: alligator, longitudinal, rutting, potholes, and reflection cracking at joints. The detailed information of each crack can be seen on the window of the hyperlink tool.

## 5. Conclusions

1. The graphical analysis showed that the maximum decline in joints layer of Al-Qadisiyah bridge at station (1+10) and equal to 16 mm which may cause a strong defect in the structure of the bridge. On the other hand, the maximum decline at the joints layer of Barboty bridge at station (2+49) and equal to 11mm.
2. The steel part of Barboty bridge has shown highly change (decline) in elevation which was equal 16 mm in side walk layer at station (2+00), therefore it is necessary to have more attention and consideration from directorate of roads and bridges in Al-Muthanna city.
3. Through the hyperlink outputs, most of the cracks that have been observed in Al-Qadisiyah bridge are Alligator cracking. In contrast, most of the cracks observed at Barboty bridge are Longitudinal cracking. The areas affected by these cracks must be maintained as soon as possible in order to not affect the surrounding areas.
4. The geodatabase which was created in this research can save time, cost, and efforts for the directorate of roads and bridges to identify the problems of bridges, which can take several days or months using traditional methods.

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