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Using of Modern GIS in Road Condition Index

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ABSTRACT
The maintenance of transportation assets has become a worst challenge for most of the transportation agencies over the world. In Iraq, there is a wide area of roads network has suffered neglect during the eighth and ninth decades of the last century. This paper provides a modern approach to manage road maintenance operations as it is applied on Tikrit-Tooz Road in the middle of Iraq. This study relies on ASTM D6433-03, 2004, Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys that applied into ArcGIS 10. At the time of the study, most of road segments up of Good level so the managers will be comfortable to arrange them maintenance without differed maintenance. Road segments will be updatable each year according to CI values as there is an allocated color for each level of condition.

Keywords: CI, GIS, road asset, asset management, Condition Index

1. Introduction

In the middle of the last century, transportation agencies were only interested on the main transportation facilities and the expansion of major road networks. At the end of the century transportation investments that depend on roads and bridges has grown. Accordingly, the agencies have become vulnerable of accountability as any other economic organizations. If the work continues as it is, the agencies and their owners will face many difficulties on due to the rising requirements with limited budgets and staff (FHWA, 1999). With all of the above, agencies must be prepared to be keeping up with significantly population growing to coverage the requirements of system and public. Therefore, all sections of transportation agencies will be required to focus on those critical points and provide the current and future studies and be ready to assume their responsibility of results.

Roads management has becoming increasingly complex day by day because of the huge increase in population which leads to increase in traffic volume. At the end of the last century the number of human population was 6 billion, projections indicate that in 2050 the population will exceed the 9.3 billion (Santosa & JOEWONO, 2005). Therefore, need for roads networks are increasing day by day to system that manages every assets in their system according to the life cycle of assets in terms of technical and financial in order to prepare the network to be keeping up with this massive population growth and requirements.

In the transportation world, New York State Department of Transportation (NYSDOT), (1998) defined asset management as a systematic approach of maintaining, upgrading and operating transportation assets to achieve best results as lowest possible costs. It is a group of mathematical and engineering analysis considers business principles according to economic theory. The final concept of asset management expands overall the scope of the infrastructure management system according to the accepted criteria by indicating to the human elements and other support assets and also the physical plant such as airports, highways, bridges, etc. asset management is a driven goal system that usually been like a traditional planning process that needs to the strategies of collection, evaluating, programming and feedback. The model of asset management shows clearly the integration of decision making overall operation areas. Simply, the purpose of asset management is to develop the benefits of transportation programs in order to make it keep pace with the requirements of the users starting from the clear goal to develop resources. As well as the assets of infrastructure can be maintained according to new determined condition, the deferred maintenance and the life-cycle cost will decrease (Yarnell, 2004).

Ozernoy et al. (1981) defined Geographic Information Systems (GIS) as an automated set of function which able to be Keep up with changing and development by storage, processing and display and the possibility to retrieve geographical spatial data.

Geographic Information Systems have played a major role to develop spatial data information of federal and state and private sector agencies. It is able to define the position of each asset and its proximity to another asset, and each event and its proximity with another events (Hegyi & Mookerjee, 2003) therefore, using of modern GIS in utilities become more advanced than the past using as computerizing mapping systems. Now, it is able to provide a model of connection to distribute facilities of utility as a computerized representation of the functional organization of the network. GIS can describe individual facilities regard of engineering characteristics, relationship with other facilities, and perform of their function.

This model is a nucleus of the wide set of applications the utility can use to support its operations (Kindrachuk, 2001). Although Geographic Information Systems is a new technology but it has been used in many different aspects of Asset Management. In Europe and North America, use of GIS in Asset Management is becoming a standard approach. Use of GIS in road asset management give more accurate outcomes if we compare it with some other road asset management software's(Sidh & Tripathi, 2006)**.** When Geographic information system combined with other modern technologies represent powerful tool for planning and managing (Guler & Jovanovic, 2004).

2. Literature Review

Vasudevan, (2004) implemented a program of road asset management according to (GASB 34) using GIS as a small public works agency. The tasks of this study are creating condition estimation manual, assets inventory, which include Global Positioning System (GPS) coordinates and asset evaluation then integrate it with GIS. This information inputted into Microsoft Excel and updated it manually at the different levels of program then integrated it with GIS which develop the program by better data query, analysis, and display. The methodology applied in Cole Country Public Work Department in Missouri, Columbia. The study follow the principles of modify asset management method because asset has an expensive maintenance cost and it is need periodic maintenance and can provide a political support, at these factors modify method is better (FHWA, 2000). Asset inventory include roads, sign, culverts, guardrails, and pipes. Road inventory include four types of road in the country: asphalt, gravel, gypsy, and concrete. Each type of road classified as one of five condition levels: excellent, good, fair, poor, and failed. Other assets (signs, culverts, guardrails, and pipes) classified as one of three condition levels: good, fair, and poor. The study provides "Unique Identifier" (UI) to link the program with GIS. UI is a utilized code includes five digit alpha-numeric refers to each asset into system. This program represents a first point for the country and created for the current condition only as the Input Sheet able to update for any future changing. The study recommended the country to inventory one-third of assets every year and check the actual replacement cost for construction costs in the country. It is enhance the capability of government to identify asset performance level and help them to estimate the actual needs to maintain roads assets according to their condition.

ASTM D6433-03, 2004 is Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys. It is provide an approach to determine Condition Index (CI) that will be relied to specify the level of service for asphaltic and concrete roads. This practice focuses on the determination of roads and parking lots road condition by visual surveys using the Pavement Condition Index (PCI) approach of quantifying pavement condition as shown in figure 1.

The PCI for roads and parking lots was developed by the U.S. Army Corps of Engineers. It is further verified and adopted by Department of Defense (DOD) and American Public Works Association (APWA).The values stated in inch-pound units are to be regarded as the standard but in this study we used it as meter-centimeter units. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

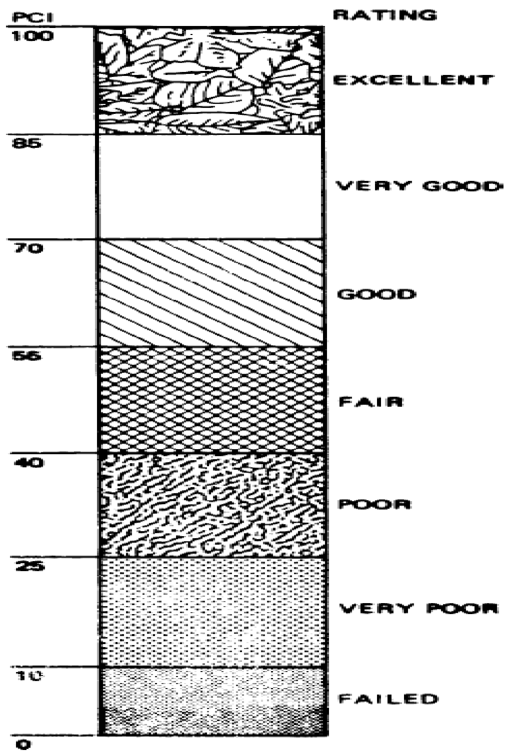


Fig. 1: Pavement Condition Index (PCI) and Rating Scale(ASTM D6433-03, 2004)

SDDOT, 2009 and WDOT, 1992 provide manuals were considered to use but they didn't refer to sufficient types of roads as they deal with asphalt and concrete roads only. WTIC, (1989) provided a set of manuals for different road types with the rain scale from 1 to 10. But this scale will need to complex matrix to make the rehabilitation decision.

Anastasopoulos, (2009) studied a case of infrastructure asset management as a pavement rehabilitation study. It is concerned to evaluating infrastructure service life, and particularly to implement treatment of pavement rehabilitation. He would to extend the traditional management way of infrastructure assets, in general, and of road, in particular, by formulating methodologies that enable transportation agencies to evaluate the effectiveness of their asset and road maintenances with respect to each maintenance service life. The study focused on six road rehabilitation maintenances in India:

a. Two-course hot-mix asphalt (HMA) overlay with or without surface milling.
b. Concrete road restoration.
c. Three-course HMA overlay with or without surface milling.
d. Three-course HMA overlay with crack and seat of Portland cement concrete (PCC) road.
e. 3-R (resurfacing, restoration and rehabilitation) and 4-R (resurfacing, restoration, rehabilitation and reconstruction) overlay treatments.
f. 3-R/4-R road replacement maintenance.

The analysis is implemented separately for urban and rural interstates, non-interstates of the National Highway System (NHS), and non-interstates that do not belong to the NHS. As road condition indicators, the international roughness index (IRI), road condition rating (RCR), rut depth, and surface deflection (which can be used only for the structural treatments) are utilized. The study selected nine years from 1999 to 2007. It selected the roads that have information over the selected period such as road condition, rehabilitation cost, road section length, traffic loads, weather and soil information, etc.

Analysis study involves three stages:

a. Determine the indicators of asset performance and estimate the performance of asset by accounting the potential simultaneous relationships among the indicators.
b. Identify the criteria of asset performance condition and estimate the thresholds of performance condition.
c. Approximate the service life of asset maintenance and determine the factors of important influential that significantly affect it.

3. Research Methodology

3.1 Map Digitizing

One of most modern programs in geographic information systems is ArcGIS 10 which is one of the families of geographic information systems that have contributed to the completion of the GIS. It has launched by ESRI and experiments by easily to insert maps and data into without urgent need to significant experience for using remote sensing programs. ArcGIS is one of the most important programs of assistance on the analysis of spatial data and assist in the decision-making(X. Liu, Lu, Mao, & Liu, 2010).

In order to digitize accuracy features, we will need to import satellite images that provide ability to be the spatial reference which matches with GPS's coordinates. According to Hegyi & Mookerjee, (2003), the highest resolution satellite image which called Quickbird imagery as the resolution is 0.61 meter.

GPSmap76SGARMIN GPS will used to collect the coordinates of the features as road coordinates refer to the center line of the road. GPS readings will collect at culverts, cities entrances, and villages and at the starts and ends of roads, road curves, and bridges. Road stations will pointed per 100 meters over the road.

AreGIS 10 has a modern Editor tool that can digitize features according to feature type as Points tool used to points features (such as culverts, stations, and cities entrance) and Polyline tool has used to vector features (such as roads, rivers, and electrical wires) and Polygon tool used to polygon features (such as seas, lakes, and farms). The whole digitized map will be able to add information and details for each asset that included going ahead into Asset Management plan. Each 1 km of the road will represent an asset to achieve more accuracy and efficiency.

3.2 CI calculation

"A Condition Index (CI) is a snapshot look at the condition of a part or componentof infrastructure" (Foltz, Howdyshell, & Mckay, 2001). It is a percentage rate graded to 100 refers to the condition of an asset as shown in ASTM D6433-03 -Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys- will used to determine the CI for each asset as it provides curves prepared to determine CI. CI amount depends on the type, shape, long, and area of cracks in the surface of the sample. We will cut out a part of each asset to determine CI as the manual refers to the type of this road need to cut out 7 m width and 30 m long as a sample of each asset of the road(MTC & ERES, 1986).

3.3 Remaining Service Life Estimation

"Remaining service life (RSL) has been defined as the anticipated number of years that a pavement will be functionally and structurally acceptable with only routine maintenance"(GEDAFA, 2008). There are two types of remaining service life can be calculated: technical service life and economic service life. Novak, (2011) provide table 1 to estimate technical RSL depending on the Pavement Condition Index (PCI) which has calculated.

Table 1:Remaining service life depend on PCI (Novak, 2011)

PCI - Description			
PCI	Description	Remaining Life	Rehabilitation Options
86-100	Good	15-25 Years	Little or no maintenance required
71-85	Satisfactory	12-20 Years	Routine maintenance - patching, crack sealing with surface treatments
56-70	Fair	10-15 Years	Thin overlays, hot mix rubberized asphalt overlays
41-55	Poor	7-12 Years	Routine Moderate to thick overlays
26-40	Very Poor	5-10 Years	High percentage of surface to full reconstruction
11-25	Serious	0-5 Years	High percentage reconstruction with possible subgrade stabilization
0-10	Failed	None	Complete reconstruction

4. Results

4.1 Map Digitizing

Using of ArcGIS 10 was a contributing factor to achieve the digital inventory quickly. As well as using of GIS in Iraq has not long ago, SGISC hasn't sufficient digitized features that have needed in this study. Therefore, we compelled to digitize all features that we need it in order create a digital asset inventory for Tikrit-Tooz road.

In order to cover the whole area of study we needed about 2500 square kilometers of Quickbird images so it is needed to add other snapshots to cover the surrounding area. Digital Globe satellites picked-up these snapshots as different weathers and seasons. The weather of Iraq is very variable and also has varying intensity dust storms during most times of year. These varying storms cause difference clarity among Quickbird snapshots for study area. When we collect these snapshots, the clarity difference was much shown. Although of this difference the whole Quickbird image was very useful to go ahead in our digitizing as clarity difference did not affect the image resolution. Figure 2 shows the whole Quickbird image for the area of study.

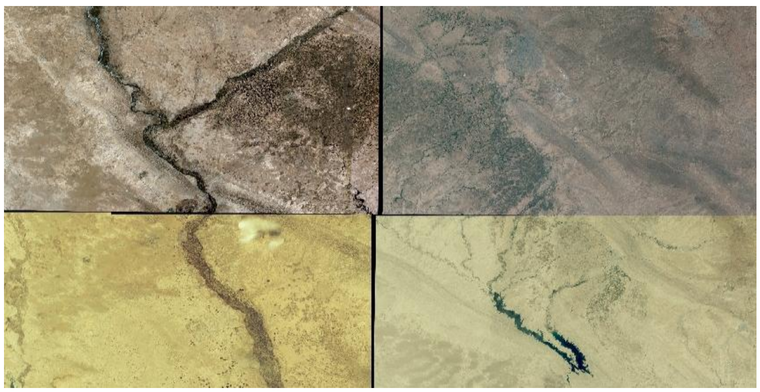


Fig.2 The whole Quick bird image for study area

This image needs to GPS's coordinates to integrate it into ArcGIS in order to specify the required spatial data then to digitize the road features which will represent the digital asset inventory. We used this image to collect the coordinates to the sites that have been uncollectable coordinates and to correct any mistake into path digitizing as shown in figure 3 as black line refers to the current road (proposal no.1), celestial line refers to alternative path that links with an existing asphaltic road ahead to Tooz (proposal no.2), red lines refer to the roads that will passed while bridge flooding, and black spots refer to villages around the proposed road. The road divided into asphaltic assets as each 1 km represents one asset. This dividing will provide accuracy in CI calculation more than previous studies as it provides once condition index for the whole road.

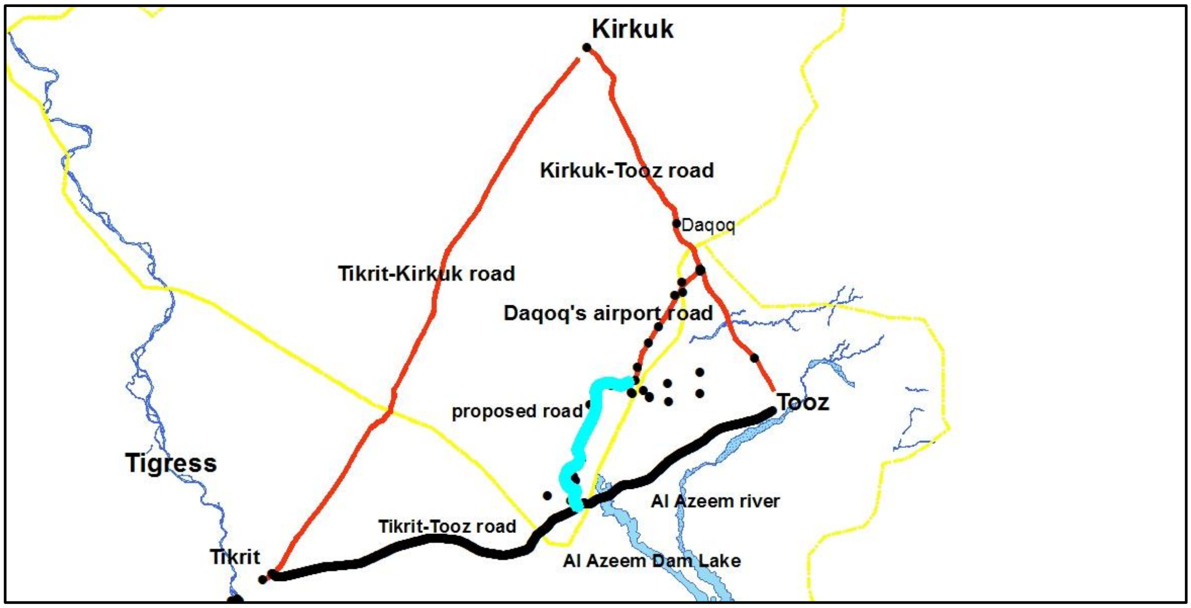


Fig.3
The final digitized map

4.2 CI DETERMINATION

ASTM D6433-03 -Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys- used to determine CI for each 1 km of the road as it provides curves prepared to determine CI for flexible roads. The worst part in each asset has been chosen with 7.5 * 30 m dimensions and measures the cracking and deflection according to its type (line or area) and calculate it as shown in Appendix A, (L) refers to (Low Distress) and (M) refers to (Medium Distress) and (H) refers to (High Distress). The road included Alligator Cracking, Block Cracking, Distortion, Longitudinal Cracking, Patching, Rutting, Weathering and Raveling as the test table divided according to it respectively. Total distress divided by sample (7.5 * 30 m^2) to find the percent of Density. Using of Appendix B by Density and Distress Level (L, M, or H) found the Deduct Value. By Total Deduct Value and Maximum Deduct Value and using curve in Appendix G we found Corrected Deduct Value (CDV) as Condition Index (CI) equal to 100 – CDV. This approach followed for all road segments expect new asphaltic road as it estimated as IC equal to 100. All IC values have inputted into ArcGIS with its features as shown in figure 4.

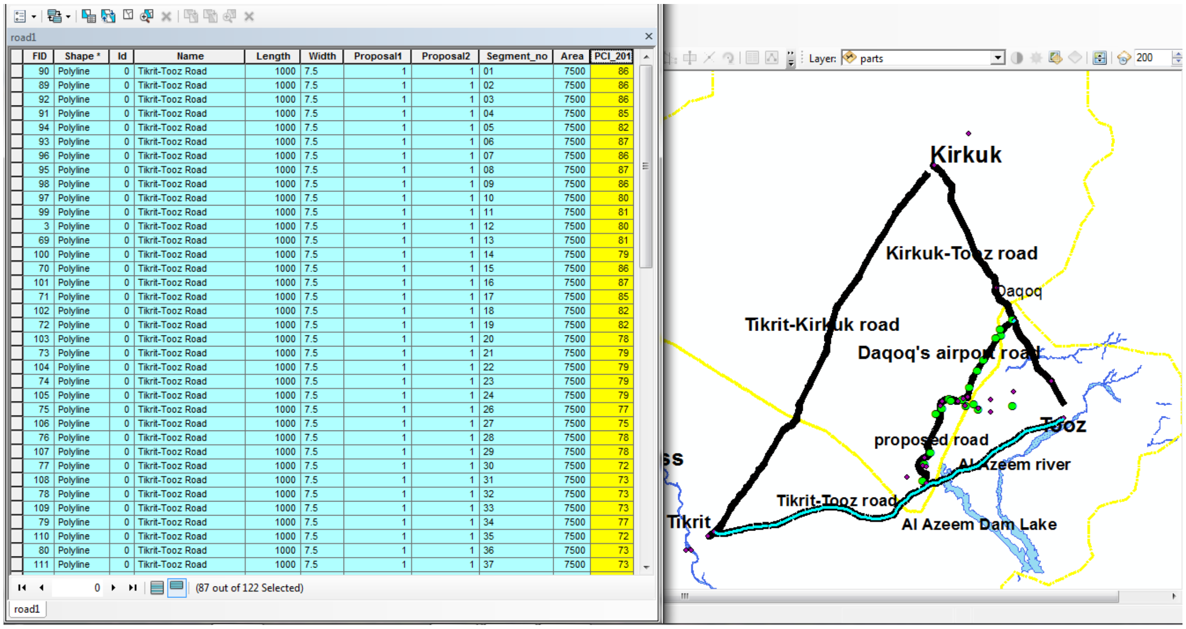


Fig.4 Assets' Condition Index into ArcGIS

4.3 RSL ESTIMATION

Depend on CI values; remaining service life can be estimated using Novak's table as shown in table 2 as color column refers to values' color into ArcGIS in 2011 as shown in figure 5. Remaining Service life divided for each 3 years to follow common maintenance operations in Iraq. GIS's symbols are able to be updated every year but in this case, managers can update it every 3 years to estimate remaining service life to do the best maintenance operations.

Table 2: Estimated Remaining Service Life in 2011 according to Condition Index

PCI	Description	RSL (year)	Rehabilitation Options	Color
91-100	Excellent	24	No maintenance required	
81-90	Very Good	21	Little or no maintenance required	
71-80	Good	18	Routing maintenance - Patching	
61-70	Satisfactory	15	Crack sealing with surface treatments	
51-60	Fair	12	Thin overlay, hot mix rubberized asphalt overlay	
41-50	Poor	09	Routing Moderate to thick overlays	
31-40	Very Poor	06	High Percentage of surface to full reconstruction	
21-30	Serious	03	High Percentage reconstruction with possible subgrade stabilization	
0-20	Failed	00	Complete reconstruction	

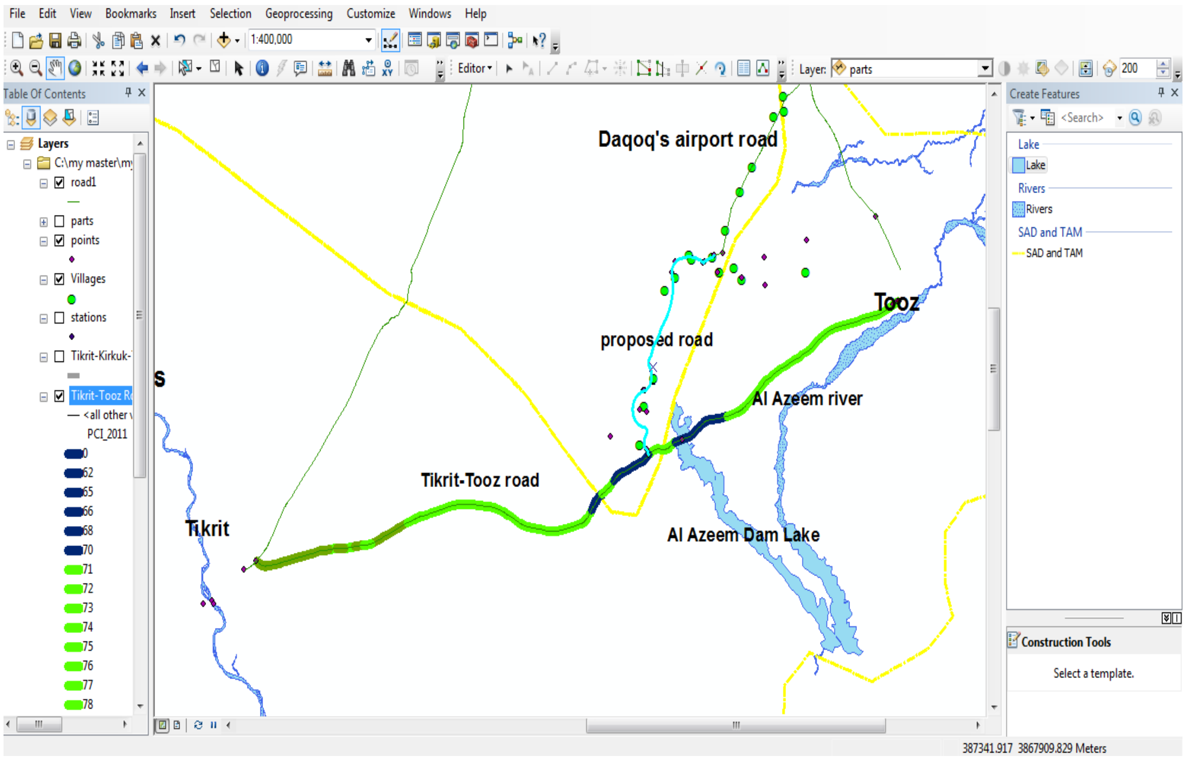


Fig.5 Technical RSL's Symbology in 2011 into ArcGIS

5. Discussion

This study applied ArcGIS 10 applications to a simple road in a region that hasn't managed before so it was necessary to create the whole system elements and make it updatable to be managed for next years. This methodology is applicable for any other roads although it focused on asphalt assets only as ArcGIS 10 able to divided different type of assets as different type of layers and present it as different colors. The future studies will be forced to face a problem with Quickbird image as it is very difficult to get it as it is very expensive and need to an organization to buy it like SGISC.

According to ArcGIS's analysis tool; there are 14 km, assets, described as **satisfactory**level which refers that this asset needs to crack sealing with surface treatments at analysis time and will be needed to reconstruction in 2026. 57 km, assets, described as **good** level which refers that this asset needs to routing maintenance at analysis time and will be needed to reconstruction in 2029. 16 km, assets, described as **very good** level which refers that this asset needs or unneeded for little maintenance at analysis time and will be needed to reconstruction in 2032. There is no asset that need to major maintenance or reconstruction. Managers will be able to compare three types of necessity; financial, physical, and specifications instructions, sometimes Condition Index refers to that assets able to be used for 15 years while specification refers that it is able to be used for 10 years only and so on.

References

ASTM D6433-03. (2004). Standard Practice for Roads and Parking Lots Pavement Condition Index. Practice. West Conshohocken: ASTM international.

Anastasopoulos, P. (2009). Infrastructure asset management: A case study on pavement rehabilitation. Policy. PURDUE. Retrieved from http://docs.lib.purdue.edu/dissertations /AAI3378685/

FHWA. (1999). Asset Management Primer. (Federal Highway Administration’s Office of Asset Management, Ed.)Management. New York: U.S. Department of Transportation. Retrieved from www.fhwa.dot.gov/infrastructure/asstmgmt/amprimer.pdf

FHWA. (2000). Primer□ : GASB 34 (Federal Highway Administration, Ed.)Director (p. 50). New York: U.S. Department of Transportation. Retrieved from http://knowledge. fhwa.dot.gov/tam/aashto.nsf/All+Documents/48EBB7A7A8C7A81B85256C55005E986E/$ FILE/GASB Primer.pdf

Foltz, S. D., Howdyshell, P. A., & Mckay, D. T. (2001). Understanding Condition Indexes Current Status and Future Opportunities (pp. SR-01-12). U.S. Army Corps of Engineers (HQUSACE). Retrieved from http://owww.cecer.army.mil/techreports /Foltz_CI_Benefits/Foltz_CI_Benefits.pdf

Gedafa, D. S. (2008). Estimation Of Remaining Service Life Of Flexible Pavements. Kansas State University. Retrieved from http://krex.k-state.edu/dspace/bitstream /2097 /1026/1/DabaGedafa2008.pdf

Guler, H., & Jovanovic, S. (2004). The application of modern GIS technology in the development of railway asset management systems. IEEE International Conference on Systems, Man and Cybernetics (Vol. 5, pp. 4153–4158). IEEE. doi:10.1109/ICSMC.2004.1401182

Hegyi, F., & Mookerjee, A. K. (2003). GIS and GPS based asset management for Road and Railway Transportation Systems in India. Map India. New York: GIS development. Retrieved from http://geospatialworld.net/index.php?option=com_content&view=article&id=16492%3Agis -and-gps-based-asset-management-for-road-and-railway-transportation-systems-in-india&catid=166%3Autility-transport&Itemid=41&limitstart=3

Kindrachuk, G. (2001). Integration of asset management and GIS. GIS development. Retrieved from file:///C:/my master/GIS and asset management/Integration of asset management and GIS.mht

Liu, X., Lu, W., Mao, J., & Liu, Y. (2010). Assistant decision-making modeling of project site location and its application based on ArcGIS Processing. and Image Processing (, 1683-1687. Retrieved from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5685136

MTC & ERES. (1986). Pavement Condition Index Distress Identification Manual For asphalt and surface treatment pavements. Transportation (2nd ed.). akland, California: metropolitan transportation commission. Retrieved from http://www.mtcpms.org/publications/asphalt PCI book.pdf

NYSDOT. (1998). Blueprint for Developing and Implementing an Asset Management System, Asset Management task force. New York: New York State Department of Transportation. Retrieved from http://www.fhwa.dot.gov/ infrastructure/asstmgmt /diny06.cfm

Novak, K. (2011). Analyzing Pavement Distress Data in MicroPaver. Annual TRB Meeting. Retrieved from http://www.transmap.com/?p=636

Ozernoy, V. M., Smith, D. R., & Sicherman, A. (1981). Evaluating computerized geographic information systems using decision analysis. Interfaces, 11(October), 92-100. Retrieved from http://interfaces.journal.informs.org/content/11/5/92.full.pdf+html?sid=9b8b9fd4-1ad9-41cb-9bb0-c5720349d905

Sddot. (2009). Enhanced Pavement Management System: Visual Distress Survey Manual. Management. South Dakota, USA: South Dakota Department of Transportation. Retrieved from http://www.sddot.com/pe/projdev/docs/distressmanual.pdf

Santosa, W., & JOEWONO, T. B. (2005). AN EVALUATION OF ROAD NETWORK PERFORMANCE IN INDONESIA. Transportation, 5, 2418 - 2433.

Sidh, K. & Tripathi. S. (2006). Road Asset Management Using GIS. Map India. Pune,INDIA: GIS developement. Retrieved from http://www.scribd.com/doc/46894142/Road-Asset-Management-Using-GIS

Vasudevan, R. (2004). Implementation of GIS enabled asset management program for small public works agencies. ProQuest. Missouri-Columbia.

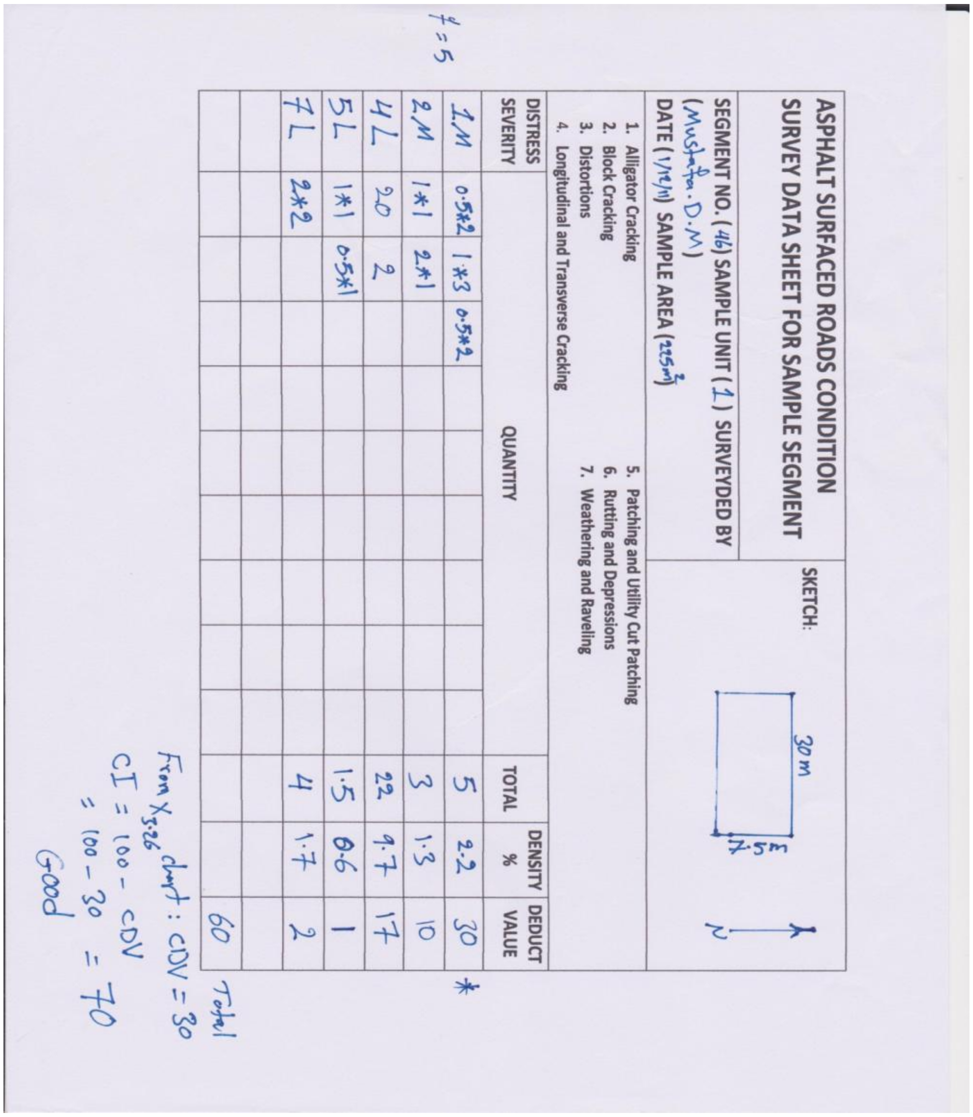
WDOT. (1992). pavement surface condition rating manual. Transportation. Washington, USA: Washington State Department of Transportation. Retrieved from http://www.wsdot.wa.gov/NR/rdonlyres/1AB0E29D-72D7-466A-9547-C9F631B4CE6C/0/PavementSurfaceConditionRatingManual.pdf

WTIC. (1989). Pavement Surface evaluation and rating. Wisconsin, USA: Wisconsin Transportation Information Center. Retrieved from http://tic.engr.wisc.edu/Manuals/Asphalt-PASERcover_02.pdf

Yarnell, C. (2004). Asset management, GASB 34, and the local entity perspective. Leadership and Management in Engineering, 4(1, January), 10-13. Retrieved from http://trid.trb.org/view.aspx?id=686242

roads net. (n.d.). Retrieved from http://www.scrb.moch.gov.iq/ENGLISH/eroads net.htm

APPENDIX A
Condition Index determination sheet



ASPHALT SURFACED ROADS CONDITION
SURVEY DATA SHEET FOR SAMPLE SEGMENT

SEGMENT NO. (46) SAMPLE UNIT (1) SURVEYDED BY (Mustafa. D.M)
DATE (1/12/11) SAMPLE AREA (225m²)

SKETCH:

1. Alligator Cracking
2. Block Cracking
3. Distortions
4. Longitudinal and Transverse Cracking
5. Patching and Utility Cut Patching
6. Rutting and Depressions
7. Weathering and Raveling

DISTRESS SEVERITY	QUANTITY			TOTAL	DENSITY %	DEDUCT VALUE
1M	0.5*2	1*3	0.5*2	5	2.2	30 *
2M	1*1	2*1		3	1.3	10
4L	20	2		22	9.7	17
5L	1*1	0.5*1		1.5	0.6	1
7L	2*2			4	1.7	2
						60 Total

q = 5

From $X_{5\text{-}26}$ chart : CDV = 30

CI = 100 - CDV

= 100 - 30 = 70

Good