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Role of GIS in Enhancing the Pavement Management System

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ABSTRACT. *Geographical Information Systems (GIS) have being used for several decades for its practicality in all aspects of applied sciences, engineering applications and governmental works as well as applications in private sector. GIS offers an ease of applicability to the works that can take immense amount of time to perform manually. Although, building a GIS network requires a lot of monetary investment at the initial stage, the investment pays off in a very short time. Pavement management systems (PMS) is a program for developing the quality and execution of road by top management mechanism. Thus Geographical Information Systems (GIS), with their spatial investigation abilities, coordinate the land idea of the street systems, they are viewed as the most suitable devices to improve Pavement management (PM) the activities, with highlights, for instance, graphical view of road condition. Today, most of the widely used online road networks are essentially based on GIS which allows users to forecast various properties along the pavement networks. In this paper, it will be aimed at showing the most critical benefits of using Geographical Information Systems in Pavement Management Systems. A comparative work is being planned such as showing some applications of PMS by performing it manually and automatically with GIS. Also, applications of the tools for pavement management systems that are adopted world widely such as pavement condition index (PCI) will be highlighted with a special focus on the integration with GIS.*

Keywords: GIS, PCI, PMS

1. INTRODUCTION

Heywood et al., (2011) analyzed the meanings of GIS from different researchers and summarized that the definitions spread the accompanying principle segments [1]:

- GIS is a program and use by computer system
- GIS utilizes spatially referenced information
- GIS completes different information investigation errands

Although GIS was definition by Burrough in 1986 “as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes” [2]. GIS has included two types of spatial data, vector, and raster as shown in Fig 1 the first one is vector spatial data which it can display all quantities data in GIS, and the second one is raster that it can any type of digital images, like a representation of topography or aerial photograph [3, 4].

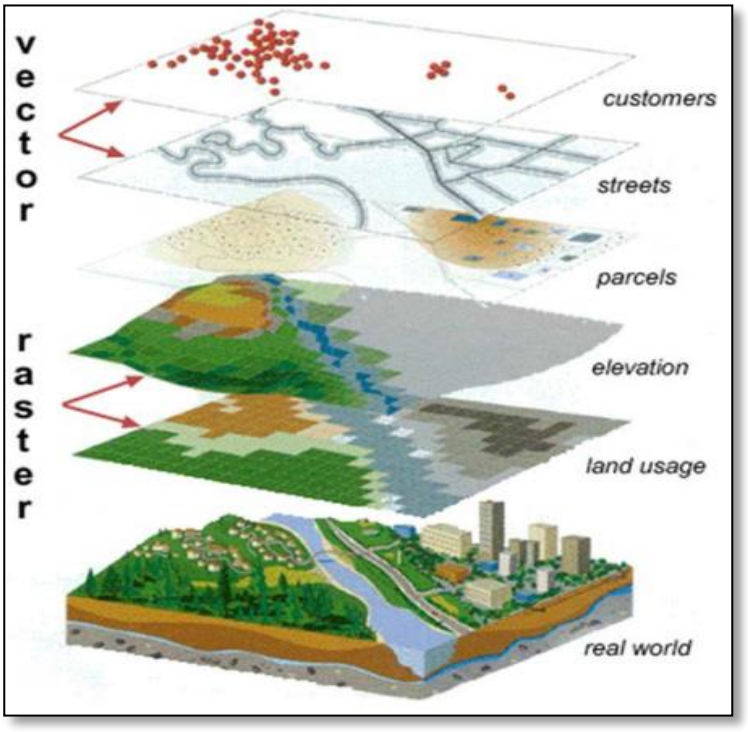

Fig - 1: Example of GIS vector and raster data [3, 4].

2. GIS HISTORY

Gray (2006) expressed that the advancement of GIS returns to 1855, while John Snow found information about 'cholera epidemic' in United Kingdom (UK) thru generating a dot map [5]. Subsequently, the utilization of geographic visual in regions pulled in consideration after this revelation [5]. In Fig 2 as demonstrated the dot map.

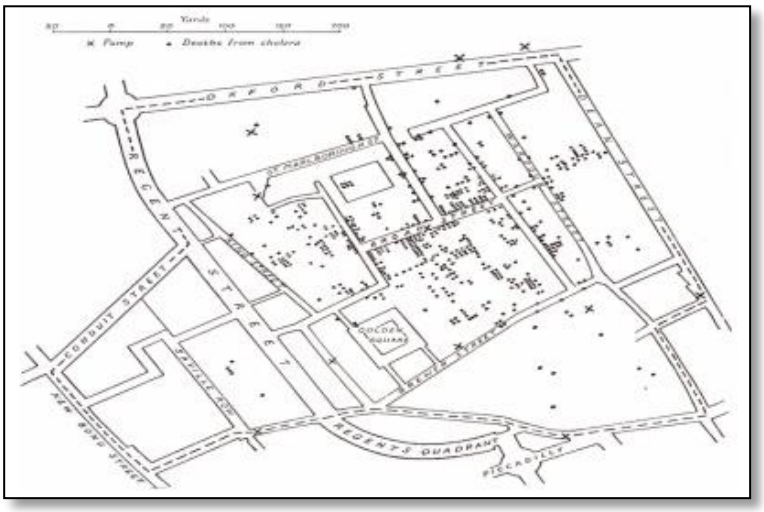

Fig -2: Shown the Dot Map of Cholera Epidemic [5].

Alfar, (2016) evaluated "the starting point of computer-based GIS, during 1960s and 1964, the Federal Department of Energy, Mines, and Resources in Ontario developed the first operational GIS and Roger Tomlinson, who became known as the father of GIS, called it Canadian Geographic Information System. Canadian Geographic Information System was used to store, analyses, and manipulate data. GIS packages were offered to public and private organizations in the 1970s and the Environmental Systems Research Institute (ESRI) was the leading seller of GIS software" [6]. ESRI publish the Arc Info package in 1981, and from that point forward, a few refreshed GIS bundles have been released [7].

3. GIS COMPONENTS

Based on Harvey, (2015) describe the five key components of GIS [8]; software, data, people, hardware, and method as shown in Figure 3 at bellow.

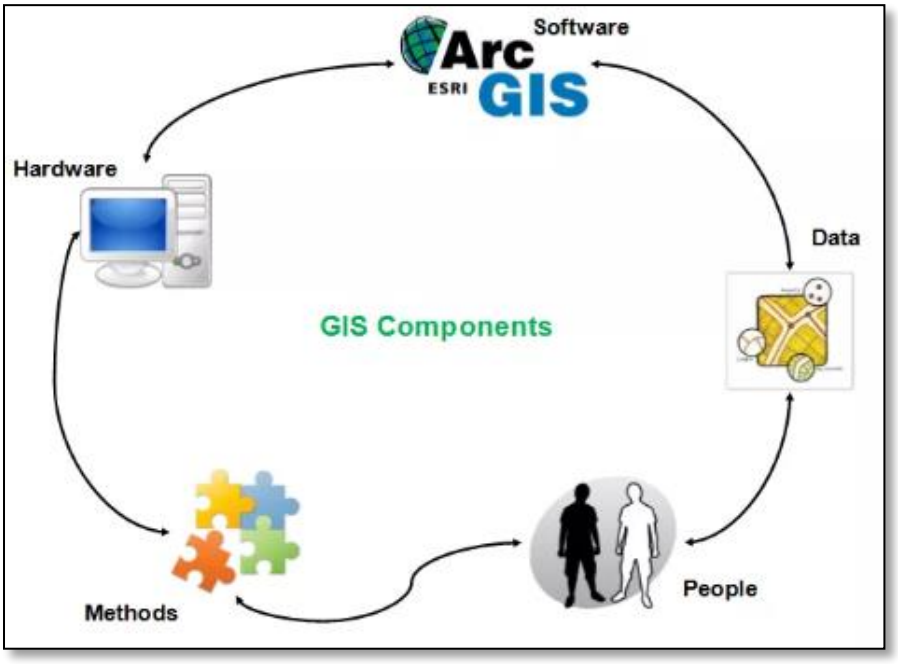

Fig - 3: GIS Components [8, 9, 10 and 11].

Hardware: GIS is working on computer system [8]. The most types of hardware were arrange to computer servers and from server starting the networking configuration.

Data: data is one of the most important part of GIS [9]. Geographic and tabular data was collected from social area or buy from commercial provider

People: GIS is limited value and without people is nothing [10]. The people can manage the GIS system and improve the plans to applying it to universal problem.

Software: GIS is computer system and can be provided tool and function for analysis, store and shown GIS environment map [11]. Also the Key software components are:

- It is tool for inputting data or operation of geographic data.
- Storage administration method.

- It is a program to develop the geographic visualization, query, and analysis.
- Those people using the GIS that it's easy access program.
- The most famous development GIS software are Arc/Info provide by ESRI, Intergraph provide by Intergraph, MapInfo provide by MapInfo, etc.

Strategies: An effective GIS works as indicated by a well-planned arrangement and business rules, which are the models and working practice interesting to every association [11].

4. GIS PROCESS

GIS process include five basic elements [12]. These are:

i. **Data acquisition**: it is a processing for data collection based on application demand. In Table 1 shown the data acquisition.

- Collecting new information by big scale maps from field area inspection as well possible to agreement to aerial photography [12].
- Finding and getting existing information, for example, maps, elevated and ground photography, overviews of numerous sorts, and reports, from files and archives [12].

Table -1: Data Acquisition Approach [12, 13]

Data Source	Method	Equipment	Cost
Analogue Map	Manual Digitizing	Digitizer	Cheap
	Semi-automatic Scanning	Scanner	High
Aerial Photograph	Analytical Photogrammetry	3rd view (Analogue Stereo plotter)	High
	Digital Photogrammetry	Digital Photo Work Station	Very High
Satellite Image	Visual Image Interpretation	Man or Image Zoom Scope	Cheap
	Digital Image Processing	Image Processing System	High
Ground Survey	Field Measurement	GPS	Very High
		Total Station	Very High
Previous Report	Keyboard Entry	Pc, Keyboard	Cheap

ii. **Preprocessing:** Manipulating the information in a few different ways with the goal that it might be entered it into the GIS [13]. It was divided into two parts;

- **Information group change**: extricating data after maps, photos, and produced records and afterward record this data save in a PC database.
- Recognizing the areas of aims in the first information.

iii. **Data Management:** The social information model is the most widely recognized one "It seems to be suitable for modelling commercial data for which humans may have the mental model of tables, such as bank accounts, telephone calls, etc. But it is not proper for modelling data that describe spatial phenomena. Relational database management systems are suitable and successful for applications dealing with weakly structured data, but they fail when they are used for applications of data with a complex structure. Since the relational data model does not match the natural concepts humans have about spatial data, users must artificially transform their mental models into a restrictive set of non-spatial concepts. The object-oriented data model is built on the four basic concepts of abstraction: classification, generalization, association, and aggregation" [14]. Many studies shown the spatial data frameworks will profit by the utilization of object-situated database the executives frameworks in different ways: The engineering of a GIS will move toward becoming more clear with the end goal that the support of GIS programming can simpler and its life cycle can longer, developers ought not stress over parts of the physical execution of information [15, 16, 17, 18, 19].

iv. **Manipulation and Analysis:** Focal point of consideration for a client of the framework. The explanatory administrators that work with the database substance to determine new data [20]. Control and examination are regularly the focal point of consideration for the GIS user of the framework. Numerous clients accept, erroneously, that this module is this comprises a geographic data framework. In this segment of the framework are the diagnostic administrators that work with the database substance to infer new data [21]. In Fig 4 as shown Manipulation and Analysis of GIS data.

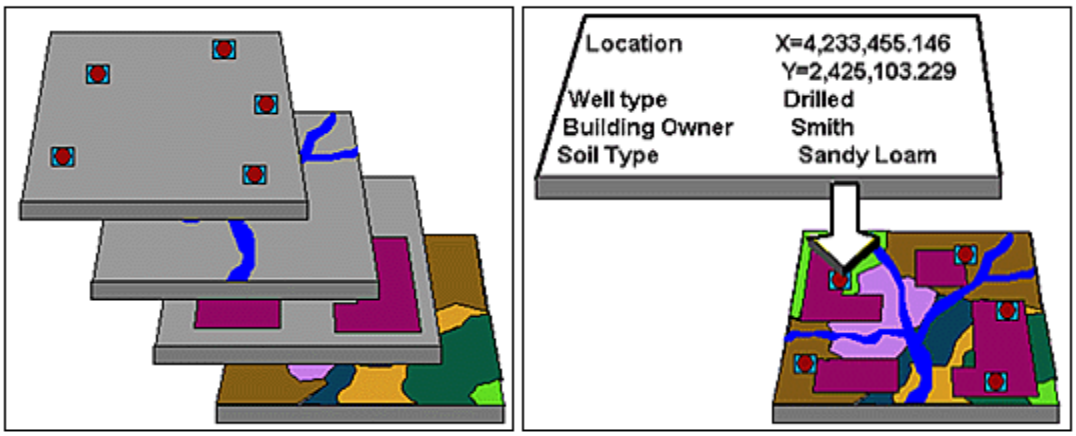

Fig - 4: Form of Manipulation data and Analysis [21]

v. **Product Generation:** Last outputs from the GIS like measurable reports, maps, and designs of different sorts. In Fig 5 as shown the product generation GIS data after analyzing [20].

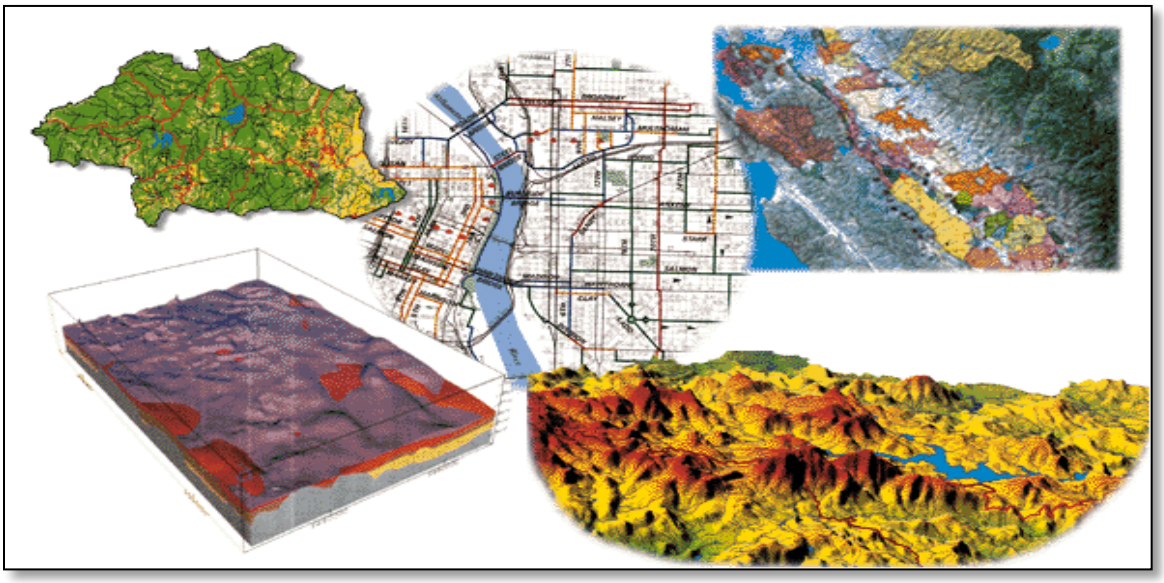

Fig -5: Product generation of GIS environment [20, 21]

5. MULTI-DISCIPLINARY APPLICATION OF GIS

GIS is an exceedingly multidisciplinary research field that has turned into a significant segment of advanced education. Ongoing articles in Nature call attention to that interest for GIS experts is thriving in light of the fact that geospatial innovations are basic for some logical research exercises and perception techniques [22, 23]. In Japan, the principal scheme of advance Geospatial data Use, endorsed by the Cabinet in 2008, defendant which HR for GIS are basic toward a 'Geospatially Enabled Society' [24]. Such developing interest for a GIS workforce is driven by the detonating utilization of geospatial advancements, involving worldwide situating administrations, area based administrations, remote detecting, spatial measurements and electronic mapping administrations [25].

While maps and cartography was once constrained to a bunch of employments, geographic data frameworks (GIS) and geographic science traverses about each field. GIS, which uses the art of geology in addition to numerous sorts of information to uncover bits of knowledge and examples that help individuals settle on better choices, is utilized in everything from urban arranging and natural protection to social insurance and advertising. While GIS jobs used to concentrate on assignments like information gathering and essential investigation, the eventual fate of this developing field is multi-disciplinary. This new methodology, in addition to the wide reach of GIS, implies the worldwide GIS market will come to an anticipated $17.5 billion by 2023. Is it accurate to say that you are keen on a vocation in GIS? Look at our information realistic beneath to adapt progressively current employments of GIS in addition to regular profession ways in this basic field [22, 23 24, 25].

6. PAVEMENT MANAGEMENT SYSTEM (PMS)

In 1980 at the first Conference of PMS in North American and in 1985 at the second Conference of Pavement management (PM) in Canada were recognized and defined them [26]. PMS “is an important tool in order to manage a road system appropriately. AASHTO regulations are used by road agencies which are dealing with maintenance and evaluation of road systems in a long service condition. PMS analyzes the most advantageous maintenance strategies and aids to apply and execute them. It relates to all occupations involved in a procedure of making a great road system. These occupations are such as, planning, initial information acquisition, maintenance, rehabilitation and construction” [26]. Pavement Management (PM) “is a tool to improve the quality and efficiency of road surfaces and reduce the costs via a good management workouts” [27].

6.1 Pavement Deterioration

Pavements are playing a significant role in social economic both in the local and national level. "The road is a key element of the pavement infrastructure. The causes of pavement deteriorations relate to these factors such as traffic volume, traffic load, environments factor-like (climate and moisture), using of poor materials during construction, quality process, weak maintenance, pavement age, and subgrade due to these causes the pavement functionally and structurally deteriorates like localized of depression, potholes, cracking, rutting, and texture loss" [28].

6.1.1 Pavement Distress

The most visible flaw or defect in the road surface is pavement distress which is one of the deterioration factors [29]. Agency "nowadays collect periodic distress data with PMMS in their surveys. Mostly the surface distress is categorized into 4 sections which are illustrated in Table 2. They are disintegration pothole, surface deformation, cracking, and surface defect bleeding" [30].

Table -2: Pavement Distress Types [28, 29, 30]

No	Cracking	Surface Deformation	Disintegration pothole	Surface detect bleeding
1	Fatigue	Rutting	Pothole	Raveling
2	Longitudinal	Corrugation	Patches	Bleeding
3	Transvers	Shoving		Delamination
4	Slippage	Depressions		
5	Reflective	Swell		
6	Blok			
7	Edge			

6.2 Importance of PMS

It would be cost approximately $13 million to restore all of Town of North Reading's 79 miles of street. an investiture this significant ought to be painstakingly protected and kept up for our occupants. "North Readings' Pavement Management Program does just that The Pavement Management Program seeks to balance preservation with replacement of existing surfaces. The most cost-efficient way to correct any street surface problem is to address issues when they first appear. That is why funds are targeted at streets rated in fair-to-good condition. Without this preventive maintenance, these streets would quickly deteriorate and be much more costly to fix. Asphalt paving material that was $40/ton in 2008 has increased to over $70/ ton in 2014. The pavement life curve shown below illustrates this point. Pavement may appear to be in good condition for a long time. However, when it fails, it fails quickly and repair costs increase dramatically. Preventive maintenance, such as crack sealing, microsurfacing, and pavement cut restoration, extends the life of our valuable street system. In addition to lowering costs over time, other advantages of our Pavement Management Program include more predictable funding needs, fewer premature pavement failures, safer road conditions and reduced time spent in traffic due to construction" [31].

7. LITERATURE REVIEW

Medina et al. [32] have aimed to develop a pavement management system for Fountain Hill district of Arizona. The road network of the investigation area was low in volume. They have first gathered the available information about the city. Then, the engineers of the municipality have provided a database with needed information. The database had the information on the condition of the pavements, as well as the cad drawing of the whole city road network. The researchers have also used some software packages related with the pavement management system part of the investigation. Also, they have used two different geographical information system software packages for the investigation. One of the software is MapInfo which is world-wide known. The other one is an integration of pavement management system as a module into the geographical information system software package. The integration allowed

the researchers to visualize the maintenance and rehabilitation needs of the city network spatially. The combination greatly reduced the amount of effort required for the management of the pavements. The authors have concluded that GIS is a very efficient tool to enhance the pavement management systems.

Picado-Santos et al. [33] have built a pavement management system for the road network of Lisbon. The city's network was somewhat enormous therefore they have needed to implement geographical information system to make it efficient. One of the team behind the study was also academicians from a neighbor university. They have begun to build the pavement management system by gathering the database of the road network. Then, the quality of the pavements has been considered by a tool which they have developed. Also, the final decision related with the pavements have been considered to be done by a decision-aid tool. The authors have separated every pavement into segments with respect to maintenance and rehabilitation urgency. This urgency was marked by a point system and shows the operation needed to fix the situation encountered. The authors also pointed out the ease of applicability of this system when geographical information systems and pavement management systems are integrated. They have strongly mentioned that this system has the advantage of visualizing the whole road network through computer screens in full color. Also, only by a mouse click would do the work and show the condition rating of each segment. Also, authors have mentioned the advantages of the built system such as a very small team consisting of three members would handle all of the city's road network including data processing and surveying. In addition, the cost of implementing such a system was found to be very low such as 0.01 cents per square meter of the whole road network.

Parida et al. [34] have aimed to build a pavement management system to quantify maintenance and rehabilitation needs and to determine the maintenance strategies by considering the overall budget. They have also mentioned that collecting, preserving and evaluating the data related with the pavement network is the most critical part of any pavement management system. Here, geographical information systems were taken into consideration as it allows spatial analysis. Also, all of the pavement networks around the world are geographical by their nature, therefore, utilizing geographical information systems for enhancing the pavement management system makes it a very appropriate tool. In addition, the capability of geographical information systems to show the pavement condition of each segment was found to be critical by the authors. The ArcView software developed by ESRI was chosen by the researchers as part of the GIS integration of the system. Authors developed a system that each of the pavement segment was evaluated in terms of serviceability level, traffic level, maintenance and rehabilitation needs. They also developed a system to allow the users to choose the correct time to intervene the pavements for the required maintenance and rehabilitation. The authors have noted that the system allows observing the detailed information related with each pavement section by a simple mouse click. Also, the integration of GIS in pavement management systems allowed the researchers to make the decision-making process much more efficient by graphical visuals.

Ferreira et al. [35] have developed a system that integrates geographical information systems with pavement management systems for Oliveira do Hospital district of Portugal. The system was stated to be developed by gathering the available information to build up a database related with the road network. Also, a quality evaluation and decision-making tool was developed for part of the system. The investigators have used the present serviceability index (PSI) for the quality evaluation of the pavements. This index utilizes generally the surface distresses such as cracking and rutting for the evaluation of each pavement section. The index also takes advantage from the AASHTO's present serviceability index. The decision-making tool was developed to take the advantage from the information of the life cycle of each pavement section for the most economical solution. Then, the authors have used the PSI value of each pavement section and implement it into the geographical information system software. According to the PSI data, maintenance and rehabilitation of each section was evaluated with respect to the severity of the roads. Finally, researchers pointed out that by using this system the maintenance and rehabilitation needs can be easily determined with respect to the correct place and time.

8. CONCLUSIONS

Utilization of Geographical Information Systems with Pavement Management Systems is a very beneficial system as it can be seen in the literature as well as in the practical life. As with all of the systems, it comes with some

drawback and some advantages. However, according to this study the disadvantages can be generally ignored as the benefits are self-paying. Some of the notable conclusions from this investigation has been given below:

- Integration of GIS and PMS requires a very demanding work at the initial stage where the systems need to be constructed from scratch.
- Utilizing GIS in PMS will immensely speed up the management of road networks for all sizes including the network of a whole country.
- The initial investment value of building such a system will return in a very short time.
- Using GIS enhances the managing of road networks by creating a very powerful visual tool for the desired area from all sizes.
- Such an immensely large system can be even controlled by a team of three persons for data processing and evaluating.
- Setting up a GIS system for managing the pavements costs several times less than pavement maintenance and rehabilitation.

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