Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.6, 2015

Using Geographic Information Systems for Monitoring Building Maintenance at the Takoradi Port

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Abstract
The maintenance of Takoradi's port infrastructural assets, such as, buildings, roads, marine structures, tower lights, is fundamental to many a Civil Engineering department whiles access to data or information of relevant aspects of the building is critical to any further analysis. Currently, retrieval of maintenance history on these assets (buildings) for the purposes of budgeting is a time consuming activity and ineffective means of accessing information. Another problem is that though data maybe available it lacks the spatial component. To resolve the above problem, Geographical Information Systems (GIS) software together with data available for the port was used. Specifically, data regarding Takoradi Port layout in AutoCAD format (input data) was acquired. By means of the GIS software (ArcGIS), a personal geo-database was created comprising relevant feature datasets such as Land use, Marine structures, Transportation and building feature class. The input data was converted into shapefiles and subsequently stored according to the various feature classes thus created in the personal geo-database. The features were then symbolized. Relevant fields for the feature class of interest (Buildings) were created in its attribute table and then populated to facilitate the query and mapping for easy visualisation of the state of the facilities. Thematic maps were also created from Structured Query Language (SQL) queries.
Keywords: Mapping; GIS; Maintenance; Building; Geodatabase.

1. Introduction

The Civil Engineering department of Takoradi Port is responsible for the maintenance of the Authority's infrastructural assets, such as, buildings, roads, marine structures, tower lights, etc. In recent years, concerns have been raised due to lack of organized historical maintenance records for such infrastructural assets. Retrieval of current maintenance history on these assets (buildings, etc) for purposes of budgeting, etc, takes time as one has to comb through several files before accessing such information. Apart from the laborious nature of the search of building information, data on the buildings obtained has no spatial component. That is to say, buildings can only be identified by names and codes but not by geographic location.

Computers offer a great deal of leverage in terms of data storage, and faster and accurate access to information. By making use of hardware, software and the data acquired on buildings it is possible to solve the above mentioned problem. This project, however, seeks to create a geo-database with Geographic Information Systems (GIS) for buildings at Takoradi Port which will offer quick access to current maintenance history (attribute data) as well as spatial data of the buildings in order to facilitate monitoring, decision support and as a reference for budget preparation for subsequent years.

2. Aim and objectives

The aim of this paper is to use GIS software to create a Geodatabase to facilitate the storage, of harbor infrastructure data for monitoring Building Maintenance Operations.
The above named aim will be achieved through the following objectives:

- Determine current maintenance history for buildings (attribute database)
- Establish a spatial database for buildings
- Integrate the attribute data and spatial data using GIS

3. Background

The long term planning and maintenance management of buildings are quite important. Taking the operation stage of the life cycle of existing building, maintenance and renovation costs may increase with a buildings age, yet there is a lack of historical data concerning the operational requirements and maintenance performance of existing buildings. Maximum "Performance life" of a building component is the time over which the component serves its anticipated function over the range from 100 % (when installed or initially placed in service) to 0% (when it fails and the only option is to replace it). However, once the level of performance falls below some minimum (just how many roof leaks are acceptable?) and the cost of continuing to maintain a failing component threatens to exceed the cost of replacement, then the component has reached the end of its "design service life" (often referred to as its "economic life") (Stanford, 2010).

Geographic Information Systems (GIS), as one branch of information technology has been rapidly developed during the last decade. It is 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 purpose. GIS is usually applied for measuring aspect of geographic phenomena and processes by representing action in form of computer database. Recently, GIS has been widely applied in the maintenance and management of buildings and other infrastructures in large cities due to its efficiency in cost and time reduction (Chaisomphob, Thitinant, Puthikanon, Kittakueng, & Viseshsin, 2001).

3.1 Building Maintenance Overview

Maintenance assists retaining economic life of buildings. It is a productive activity both at the private and the national levels. At the private level, proper maintenance leads to lower depreciation costs (due to longer economic life) and consequently leads to higher profitability. While at the national level, proper maintenance leads to lower expenditures on replacement. Thus, allowing more expenditure on expansion into new productive investment (Ikhwan, 1996). "Building Maintenance is the work undertaken in order to keep, restore or improve every facility, i.e. every part of a building, its services and surrounds to a currently acceptable standard, and to sustain the utility and value of the building" (Mills, 1980)

In addition, maintenance is defined in the British Standards (BS 3811:1974) as "A combination of any action carried out to retain an item in, or restore it to an acceptable condition" (Mills, 1980). There are two processes envisaged, retaining; i.e. work carried out in anticipation of failure. The former is usually referred to as "Preventive Maintenance" and the latter as "Corrective Maintenance". There is also the concept of 'acceptable standard'. This may be construed as acceptability to the person paying for the work, to the person receiving the benefit or to some outside body with responsibility for enforcing minimum standards. (Mills, 1980)

A more functional definition is that "Maintenance is synonymous with controlling the condition of a building so that its pattern lies within specified regions". (Shear, 1983)

3.2 The Objectives of Building Maintenance

- To ensure that the buildings and their associated services are in safe condition.
- To ensure that the buildings are fit for use.
- To ensure that the condition of the building meets all statutory requirements.
- To carry out the maintenance work necessary to maintain the value of physical assets of the building stock.
- To carry out works necessary to maintain the quality of the building (Alner, 1990).

3.3 Principles of Long Term Maintenance

Effective maintenance of building not only improves the quality of living environment but is also a vital means to uphold or even raise the value of properties. Maintenance in general can be classified into servicing; repair; and replacement and upgrading. There is also a marked difference in terms of methods, management and the result of breakdown maintenance versus planned and preventive maintenance.

According to ISO 15686 there are several types of maintenance

- Planned Maintenance
- Preventive Maintenance
- Scheduled Maintenance
- Corrective Maintenance
- Conditioned- based Maintenance
- Emergency / unforeseen Maintenance
- Predictive Maintenance
- Deferred Maintenance
- Onsite / offsite Maintenance

Planned maintenance gives the owners and the property managers, more time to prepare for the works and more importantly, to secure the necessary funding. It usually starts out by a thorough condition survey to assess the current situations, identify the full extent of works required and lay down the level of expectation. Considerations include implementation programs, standard of performance and reliability as well as maintenance strategy, budget and life cycles of certain elements and facilities (Buildings Department, 2013).

3.4 What is GIS?

In the last years, Geographic Information Systems (GIS) have become increasingly popular. More and more people have access to spatial data via GIS systems. The GIS technology has provided the means to integrate analyze and update large amount of geo-data.

A geographic information system (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates (Star & Estes, 1990)

Due to the geographic nature of the objects depicted, data in a GIS is inherently spatially referenced. In order words, each object found in a GIS can be related to some location and can be mapped. Maps are two-dimensional representations of the Earth's surface; therefore, there exists a direct translation of all geographical entities into the equivalent elements of planar geometry, i.e., "points, lines, or polygons (Cowen, 1988). The objects in a GIS are defined by their location and often by multiple attributes that further describe characteristics of the objects.

GIS can help to store, manipulate, and analyse physical, social, and economic data of a city. Planners can then use the spatial query and mapping functions of GIS to analyse the existing situation in the city. Through map overlay analysis, GIS can help to identify areas of conflict of land development with the environment by overlaying existing land development on land suitability maps (Yeh, 1999).

Integrating data has traditionally been time-consuming and expensive. GIS technology has brought advances in computer processing, graphics, and database capabilities to help solve the problems of spatial data integration. Some agencies are using GIS or other spatial technologies to integrate data and to manage the central enterprise-wide databases (National Cooperative Highway Research Program, 2004).

GIS systems can enhance the performance of measuring, mapping, modeling, and monitoring activities, but the value of the information derived from these activities depends on the quality of data used as input. Poor quality input data can cause erroneous or meaningless interpretation (Knippers, 2009).

Knowing where something happens is critically important if we want to go there ourselves or send someone there, to find other information about the same place, or to inform people who live nearby (Longley et al, 2002).

3.5 What Processes Are Involved In Using GIS?

There are four general processes involved in using GIS. Each of the processes involves the use the use of the GIS database. The database can therefore be considered as the core of the system. The processes are:

- Database creation and data entry
- System and database management
- Manipulation and analysis of spatial data
- Display and map generation

The geographic data model, implemented in a geodatabase design, is the foundation for all activities with a GIS—creating expressive maps, retrieving information, and performing spatial analysis. Designing a geodatabase to meet these goals is a deliberate process (Zeiler, 1999). Manual digitizing or scanning of maps, surveying and remote sensing are methods and techniques to capture spatial data, also known as geo-data. Government agencies or commercial companies are suppliers of existing data sets.

System and database management includes file storage capacity and controlling user access to files for reading, modifying, and archiving purposes. Data management provides standard methods for entering, updating, and retrieving data. The kernel of a GIS is therefore a database management system (DBMS) handling the storage and management of the data, as well as interaction with users (Rigaux, Scholl & Voisard, 2001).

The derived information should be presented in a clear and unambiguous way to avoid that wrong decisions are taken. Display and product generation includes creating plots, displaying statistics on data, creating cartographic products, and combining these products in reports. Some products are simply screen displays: others are hard copies of tabular files or maps, digital files for use in other computer programs (e.g. desktop mapping packages to prepare good cartographic output (Knippers, 2009).

4. Research Methodology

4.1Study Area

Takoradi port is located in the industrial city of Sekondi-Takoradi, capital of Western Region, SW Ghana, on the Gulf of Guinea. The geographic coordinates of Sekondi -Takoradi are: 4.91667^{0}N 1.76667^{0}W.

4.2 Data and Materials Used

- AutoCAD data (.dwg format) of Takoradi Port layout
- Satellite imagery of Takoradi Port (downloaded from Google earth)

4.3 Hardware and Software

Hardware:

Windows Vista Home Premium (64 bit) by Microsoft Corporation with 2GHz processor and installed physical memory (RAM) of 3.00 GB. An 8GB flash drive was used for the transfer of data.

Software:
The software utilized in this study includes ArcGIS Version 9.3, ArcReader 9.3, Microsoft Project 2010, Microsoft Word 2010 and Microsoft Visio 2010.

4.4 Data Collection and Preparation
The spatial data was obtained from the Hydro/Land Survey department of Tema port. The format and coordinate system assigned to the data were.dwg (AutoCAD) ad the Ghana Transverse Mercator (Accra TM Grids (ft)). The Transverse Mercator according to Kennedy and Kopp (1994) is similar to the Mercator except that the cylinder (developable surface) is tangent along a meridian instead of the equator, respectively.
The attribute data (current maintenance history) of the buildings could not be accessed however, a customized attribute data was created in order to successfully complete the project.

4.5 Geodatabase and Coordinate Reference System
A Personal geo-database was created using ArcCatalog, ArcGIS data management program. Using a geodatabase can be simple and straightforward. Geodatabases can be created, accessed, and managed through the standard menus and tools in ArcCatalog (Peters, 2003). The coordinate system of the Feature datasets is Transverse Mercator and datum Accra TM I NW (meters). The aim was to convert the coordinate system of the input data from Ghana Grid (ft) to Accra TM I NW, that is, from imperial to metric. The feature datasets and feature classes are broadly categorised into Land use (parcels, parks and paved open areas), Marine Structures (jetties, lee breakwater, main break water and slipway jetty) and transportation (railway, road and sea).

4.6 Data Conversion and attribute Data Entry
When using CAD, the user can begin creating a digital map without first having to complete and code an extensive database design for capturing the map. This is one reason why CAD systems can be used to create graphic data for a GIS, even if the data will have to be translated into the GIS format in a subsequent process (Schuch, 1993).

The attribute data of the feature class of interest (buildings) were entered directly into its attribute table in ArcMap environment. The "Next_Expected_Maint._Date" field for each type of building was obtained by adding the maintenance frequency (years) as indicated in the Buildings Maintenance Schedule in Table 1, to the "Last_Maint._Date" field.

Table 1 Buildings Maintenance Schedule (Civil Engineering Department (Takoradi Port), 2013)

Ref	Building Type	Maintenance Type	Frequency Of Maintenance
1	Offices	Rehabilitation(Painting Etc)	2 Years
2	Workshops	Rehabilitation(Painting Etc)	3 Years
3	Sheds	Rehabilitation(Painting Etc)	5 Years
4	Substations	Rehabilitation(Painting Etc)	3 Years
5	Public Toilets/Washrooms	Rehabilitation(Painting Etc)	2 Years

4.7 Map Production and publishing
Maps were produced in the layout view of ArcGIS out of relevant queries performed in section 4.0 below. In order to produce a standard map the following were inserted on the map- legend, scale, north arrow, Title and other relevant map information.

Using the Publisher Extension in ArcGIS, a published map document was created in the form of published map file (pmf). The PMF files could be accessed on any computer with ArcReader (a free downloadable ESRI product) installed on it. Functionalities like, identify, measurement, pan, zoom, hyperlink, find, swipe and few others can be utilized.

5. Results and discussions
The following are results cost of buildings maintained in the year 2012:

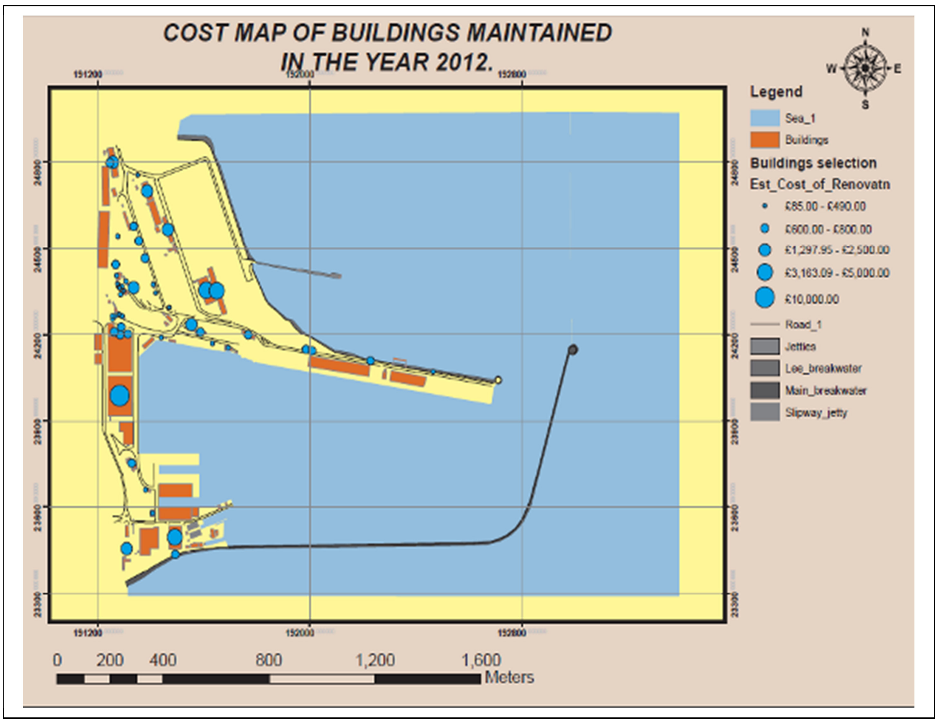

Figure 1: Cost Map of Takoradi Harbour Infrastructure - 2012

5.1 Attribute Query 1

In order to verify the functionality of the database, the following test queries (attribute queries) were performed using Structured Query Language (SQL) in ArcGIS;

For example it was possible to generate the estimated cost of maintenance carried out on all buildings in the year 2012 by performing a simple SQL query on the Geodatabase. 50 of 130 building polygons shown edged cyan colour are buildings maintained in the year 2012 with cost statistics indicated below:

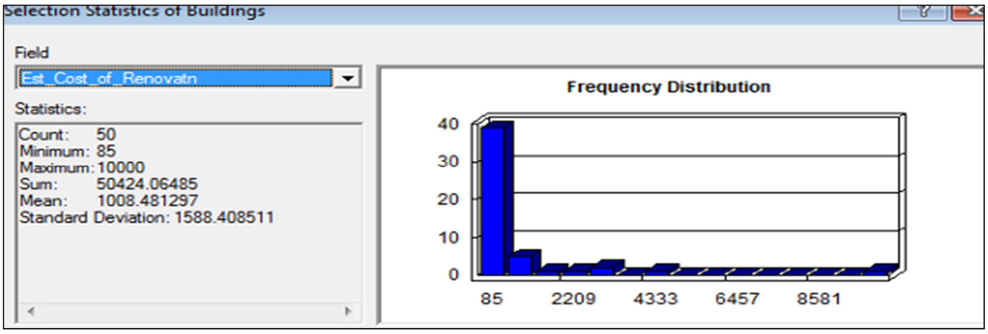

Figure 2 Results of attribute test query 1

5.2 Attribute Query 2:

Figure 3 Results of attribute test query 2 (All buildings which would be due for maintenance in the year 2014). NB: From the above query, 49 of 130 building polygons shown edged cyan colour are buildings expected to be maintained in the year 2014. Thematic map of buildings expected to be maintained in the year 2014 was also generated.

The geo-database, attribute database (of buildings) and spatial data of Takoradi Port Infrastructure are very relevant in the monitoring of buildings and other infrastructure maintenance in the port. Current maintenance history of the buildings and other infrastructure could not be obtained. However, for the project to be successful, a prototype/ customized attribute database was created for the feature class of interest (buildings). This assumed the use of the pound sterling (£).

This will offer the user (Civil Engineering department) current information on the spatial location of the buildings, who maintained it, the estimated total cost of maintenance, year of maintenance, description of work done, and condition of the buildings among others to facilitate decision support, budgeting, etc. In the first attribute query (attribute query 1) above, a statistics button launches the Selection Statistics dialog box, which displays the statistics for the entire selection set. The statistics can be viewed according to layer and attribute. A graphic representation of the distribution of each attribute is also shown. From the results, it was realized that maintenance works of various scope were executed on 50 out of 130 buildings in the year 2012. The least maintenance cost is £85.00 and maximum cost is £10,000.00. However, the estimated total cost of maintenance on the 50 buildings is £50,424.00. This would enable the department not only measure performance productivity but also check for budget over-run.

In the second selection (attribute query 2) a simple SQL statement was written to retrieve records of buildings features, the interface providing summary statistics for the query. From attribute query two, it was again identified that 49 of 130 buildings of various class or type would be due for maintenance in the year 2014. Using the previous year's actual cost of maintenance for the same type of building as the base data, the subsequent maintenance works could be budgeted for taking into consideration current economic factors and scope of work.

6. Conclusion and Recommendations

By using GIS software both spatial and non-spatial data could be integrated into a Geodatabase for better data organisation, analysis and retrieval. The feature classes created within the Geodatabase is a necessary step in creating a spatial database, which is well organised than other disparate datasets which may be, furthermore, without a spatial component. Consequently it is possible to capture the current maintenance history into Geodatabase. This application, comprising both attribute and spatial information would facilitate the monitoring, budget preparation, cost analysis, etc of buildings maintenance in the port. By extension, the Authority's infrastructural investment pattern could as well be analyzed.

A more accurate and current cost and time data will determine the reliability of the application. Furthermore, it is recommended that the GIS software be customised specifically to allow a more accurate determination of maintenance costs making use of all other parameters in the estimation such as inflation rates. According to Stanford (2010), normal cost escalation due to inflation will occur and future costs will be higher than today's costs.

References

1. Alner, G.R. & Fellows, R.F. (1990). Maintenance of local authority school buildings in UK.
2. Buildings Department. (2013, December 19). *Publications and Press Releases:* . Retrieved from Buildings Department; The government of Hong Kong Special Administrative Region: http://www.bd.gov.hk/english/documents/code/bmg/BDG_ENG.pdf
3. Chaisomphob, T., Thitinant, H., Puthikanon, T., Kittakueng, T., & Viseshsin, S. (2001). *ITC Digital Library*. Retrieved from Digital Library of Construction Info.and IT in Civ. Eng. and Const.: http://itc.scix.net/cgi-bin/works/Show?ecce-2001-42
4. Cowen, D. J. (1988). GIS versus CAD versus DBMS: What are the differences?. *Photogrammetry. Engineering and Remote Sensing.*, *54*(11), 1551-1555.
5. Ikhwan, M. Hag, A Burney., (1996). "Maintenance Management in Saudi Arabia" Journal of King Saud University, Eng. Sci. page 67.
6. Kennedy, M., & Kopp, S. (1994). Understanding map projections. *GIS by ESRI*.
7. Longley *et al*, 2001. *Principles of Geographic Information Systems and Science*. London, John Wiley.
8. Mills,E.D (1980). Building maintenance and preservation- "A Guide to Design and Management", Buttherworth.
9. National Cooperative Highway Research Program. (2004). *Pavement Management Applications Using Geographic Information Systems* (Vol. 335). Transportation Research Board.
10. Peters, D. (2003). System Design Strategies. *An ESRI White Paper*.
11. Rigaux, P., Scholl, M., & Voisard, A. (2001). *Spatial databases: with application to GIS*. Morgan Kaufmann.
12. Schuch, H. C. (1993). *GIS data conversion handbook*. John Wiley & Sons.
13. Shear, M. (1983). "Building Maintenance Management". Virginia, Rexton Publishing Co.
14. Stanford, H. W. (2010). *Effective Building Maintenance: Protection of Capital Assets*. The Fairmont Press, Inc..
15. Star, J., & Estes, J. (1990). *Geographic information systems*. Englewood Cliffs: prentice-Hall. Knippers, R., (2009) (Coordinating staff member), Jelger Kooistra, Willy Kock and Ton Mank "Principles of Geographic Information Systems (GIS), Part 1, International Institute for Geo-Information Science and Earth Observation, Enschede, Netherlands (ITC)
16. Civil Engineering Department (Takoradi Port). (2013). Buildings Maintenance Schedule. Takoradi, Western Region.
17. Yeh, A. G. O. (1999). Urban planning and GIS. *Geographical Information Systems: Principles, Techniques, Applications, and Management 2nd edition, Eds PA Longley, M Goodchild, D Maguire, D Rhind (John Wiley, New York) pp*, 877-888.
18. Zeiler, M. (1999). *Modelling our world: the ESRI guide to geodatabase design* (Vol. 40). ESRI, Inc..