

Application of GIS-Based Construction Engineering: An Electronic Document Management System

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Abstract—This paper describes the implementation of a GIS to provide decision support for successfully monitoring the movements and storage of materials, hence ensuring that finished products travel from the point of origin to the destination construction site through the supply-chain management (SCM) system. This system ensures the efficient operation of suppliers, manufacturers, and distributors by determining the shortest path from the point of origin to the final destination to reduce construction costs, minimize time, and enhance productivity. These systems are essential to the construction industry because they reduce costs and save time, thereby improve productivity and effectiveness. This study describes a typical supply-chain model and a geographical information system (GIS)-based SCM that focuses on implementing an electronic document management system, which maps the application framework to integrate geodetic support with the supply-chain system. This process provides guidance for locating the nearest suppliers to fill the information needs of project members in different locations. Moreover, this study illustrates the use of a GIS-based SCM as a collaborative tool in innovative methods for implementing Web mapping services, as well as aspects of their integration by generating an interactive GIS for the construction industry platform.

Keywords—Construction, coordinate, engineering, GIS, management, map.

I. INFORMATION TECHNOLOGY: AN INTRODUCTION

ENGINEERING application concepts have changed dramatically due to the wide spread of technology during the last century. That century was characterized by rapid changes in creative information technologies and has been rightly named “the Information Era”. This development was the natural result of the emergence, evolution, development, and spread of the computer and its applications, which have played a major role in overcoming many obstacles, creating new environments, and facilitating routine tasks. Programmers competed to create easy-to-use programs and now offer complete packages that enable engineers to complete work faster without losing time in systematic tasks. This was advantageous to engineering practice because it enabled engineers to design more complex systems. Because of these savings in computing time, more time could be invested in system optimization to obtain the most economic, efficient, and elegant design—in other words, to reach a very high standard for the construction community.

It is well known that information technology (IT) delivers a platform for data manipulation in a cost-effective and time-saving manner. IT applications have been implemented in many areas and have opened new horizons for software

developers to generate computer programs in various formats [1]. This technology has created opportunities in various fields for the planning, architecture, engineering, science, and medical health disciplines. In the construction industry, Web-based engineering software must be used to explore fully the benefits of IT. A generalized Web-based IT system has been designed to improve collaboration between construction professionals [2] by facilitating Web-based construction project management using tools that are popular in civil engineering.

A study was carried out [3] involving a decision support system for materials selection during design or construction projects by consultants and clients, which related important decisions made during construction projects to materials selection. The study revealed that high-quality materials are generally recommended after becoming aware that a high initial cost is often offset by reduced maintenance requirements.

A classical method based on a pilot project using groupware and workflow management techniques known as electronic document management systems (EDMS) was used in the civil engineering projects to locate documents graphically [4]. The procedure involved engineering documents including monthly reports, general and specific specification documents, drawings, and bills of quantities. These were considered to be integral parts of the project, and they had to be processed in a professional manner.

SCM includes phases that confirm the management of information, materials, and cash flow through a network of interested parties such as suppliers, consumers, manufacturers, and distributors, thereby reducing costs, saving time, and ensuring that business quality satisfies customers. GIS, on the other hand, depend on mapping technology to locate suppliers, manufacturers, and distributors to determine the shortest path to the final destination, and hence GIS is used as a tool to provide decision support within a successful SCM platform.

II. SCM AND GIS PLATFORMS

The construction engineering industry has recently seen record success and global expansion, causing materials SCM to grow over time, thereby optimizing production and organizing materials management. Well-known companies around the world have emphasized the importance of interacting with their consumers using efficient systems when working in the international arena in a competitive environment. Hence, SCM strategies have been implemented to improve their business performance. Supply chains involve five main participants: suppliers, manufacturers, dealers,

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retailers, and consumers, and are also influenced by five factors: information, production, inventory, location, and transportation [5], as shown in Fig. 1.

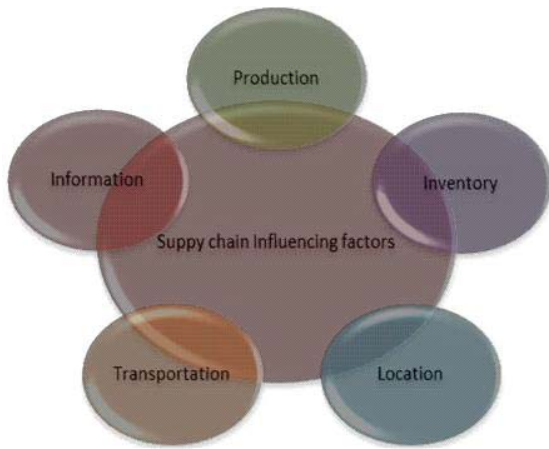


Fig. 1 Factors influencing the supply chain [5]

Construction planning and execution require materials to be available on site before activities can commence [6], but the conventional supply-chain systems lack appropriate planning capabilities, resulting in material unavailability and extra time required to locate materials.

A classic construction supply chain for building materials involves the following elements [7]:

- The model contains many interlinked supply-chain nodes.
- The raw material nodes supply raw materials to the component producers and the original equipment manufacturers.
- The manufacturer node is linked to the supplier node.
- The supplier transports the material to the construction site.

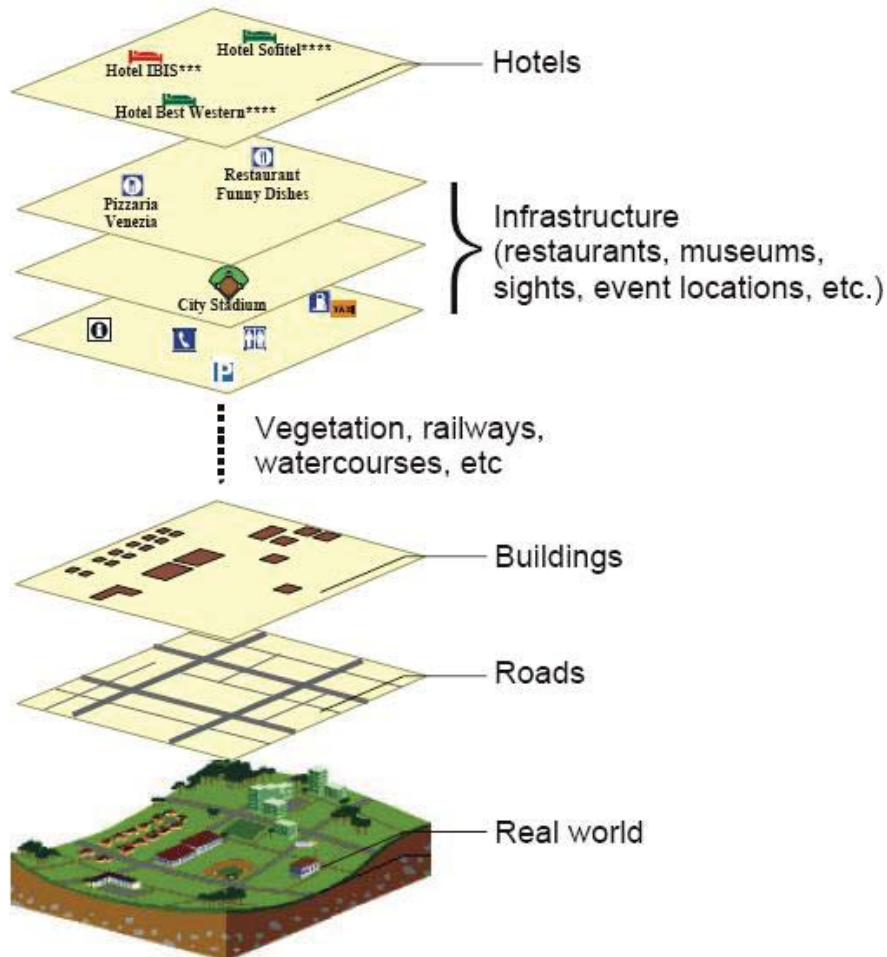


Fig. 2 GIS layer model [14]

A network includes multiple organizations [8] with information flows, such as materials, services, and funds between clients, designers, and other interested parties. A

network that facilitates the coordination of construction and SCM using an Internet-enabled mechanism can enhance the coordination process.

Potential GIS applications have been demonstrated in civil engineering as well as in the construction industry. A different approach was proposed in [9] that combined GIS-based and 4D modeling for project management under the umbrella of building information modeling (BIM). The geographic locations of local or international material suppliers have major effects on the cost, delivery time, and quality of materials that reach the construction site. GIS has been used in many disciplines, including planning, mapping, engineering, biology, geology, business practice, and health care systems. Infrastructure projects have used GIS [10] to deliver a wealth of information through a spatial interface.

A GIS-based method was proposed to replace the manual procedures for extracting knowledge from the existing databases that can be easily updated to digital format [11].

GIS has emerged as a challenging technology that enables geographers to incorporate data and methods in various ways

to support the conventional forms of geographical analysis [12]. Researchers have also noted the importance of GIS and mapping [13] as decision support systems in business applications.

Various types of GIS applications in tourism planning have been studied [14], as shown in Fig. 2. In this study, GIS was used in three types of applications: inventory, analysis, and evaluation of tourism development plans.

Techniques have been developed to select the residential housing sites by means of a decision support system [15]. A prototype application was developed for a data warehousing technique that enabled investors and other interested developers to select appropriate sites by rank order based on an availability list. This technique used GIS software at the back end, whereas a hierarchical analytic process was used in the front end. Fig. 3 shows the logical model developed for site selection.

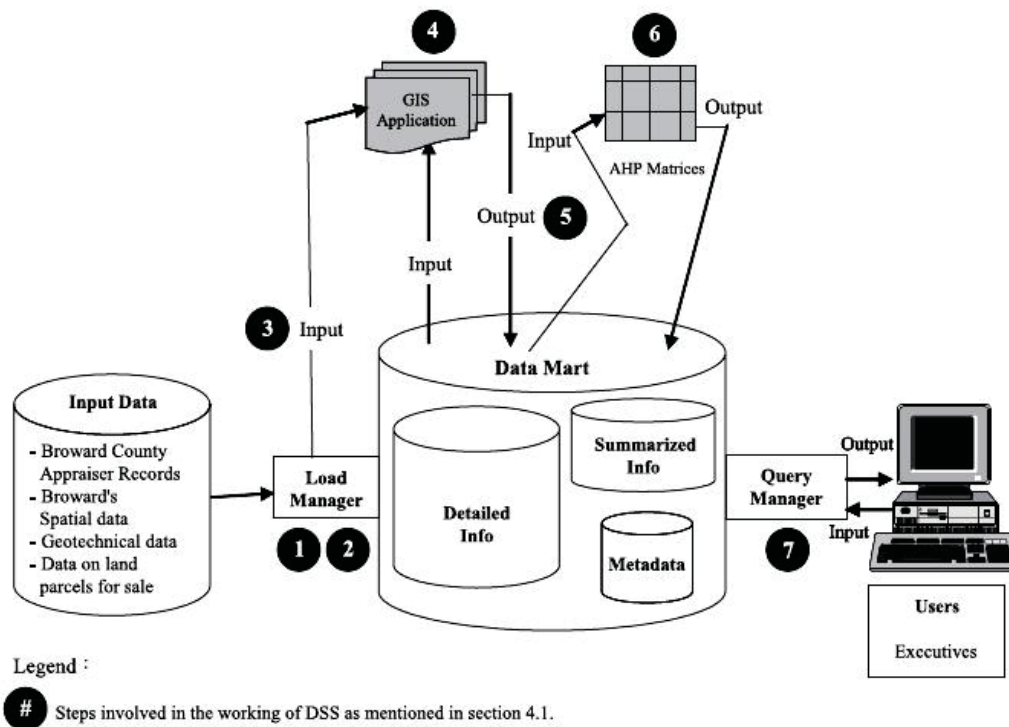


Fig. 3 Conceptual model of a decision support system [15]

GIS have been implemented in health-care systems and used in health research [16], where they can provide a spatial dimension and a tool for health applications and services. A simple illustration of the layers provided by a GIS is presented in Fig. 4.

A general study of trends in obesity and other diseases in the United States between 1985 and 2007 concentrated on basic applications, including constructing disease maps, analyzing trends in space and time, and mapping populations at risk [16].

A framework based on using a GIS to construct an SCM was developed, which incorporated Web mapping services to enhance the supply-chain process [17]. The proposed system involved the following steps:

- The system suggests the incorporation of online maps with the materials database.
- The material suppliers, manufacturers, and end users communicate throughout the entire chain.
- Materials and suppliers are located using Google or Bing maps.

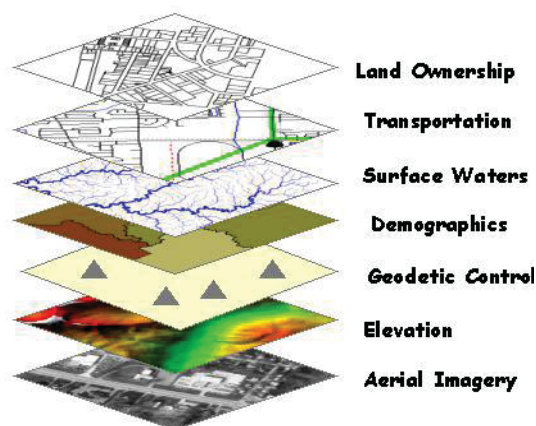


Fig. 4 Various types of layers provided by a GIS [16]

III. COMPONENT-BASED CONSTRUCTION

IT and computer engineering have well-defined roles in the construction industry and in the medical practice. Construction projects and medical practices have some similarities in terms of their function and operation, and both fields require compliant components and architectures that define how these components are grouped together to form a building or a living organism. There are also common functionalities in both fields, such as information storage and retrieval for organizing documents related to various components. Therefore, high-quality systems require efficient design and implementation to achieve their objectives.

Hardware manufacturing is an engineering process that produces many components, such as spare parts that are stored on shelves for the future use. Software engineering also includes many components that can be used in a variety of products, such as graphical windows, software applications, and interaction methods. In general, software design and construction involve logical processing rather than a mechanical product. For example, an interactive geodetic visualization system was designed to collect hurricane data from 1851 to 2009 and supports data exploration from three linked perspectives: spatial, temporal, and multidimensional [18].

IV. DEVELOPMENT PROCESS APPLICATION

In this study, the application development process used the visual business network (VB.NET) with Visual Studio and SQL Server. Model-view-controller Version 3 was used to provide desktop and mobile views of a single application, as shown in Fig. 5. The “Razor” is a new viewing engine for active server pages (ASP.NET) and was used because its syntax is compact and reduces the need for typing [19]. ASP.NET was implemented as a model, view, and controller (MVC) combination, which is an architecture that enables construction of scalable and standards-based Web applications and is illustrated in detail in [19]. The engine is structured as follows:

1. Models are classes that manipulate data.
2. Views are Web pages included in the Web application.

3. Controllers are components that handle interactions with the user.

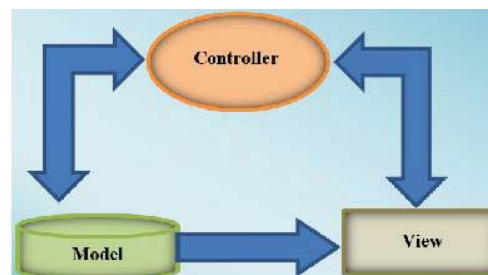


Fig. 5 Model, view, and controller in ASP.NET [19]

V. INTERACTIVE APPLICATION FOR GEO-LOCATION

Geological interactivity was added to the application using Web mapping application programming interfaces (APIs), which were implemented to create interactive mapping applications that provide map customization features. The overlays, controls, and services are API functions that are used in this application to calculate distances between multiple destinations to locate the nearest one [20]. This facilitates visual tracking of supplier locations and the site for which materials evaluation has been requested. The geo-location API defines a high-level interface for location information that is associated only with the device implementation host, such as latitude and longitude [21]. The program was written to retrieve latitude and longitude coordinates from the position argument of a Show Map method. Geographic position information was provided in terms of World Geodetic System coordinates [22], in which a Map object is created with its position, records, center, map type, and zoom level. The steps required included navigating and creating locations, adding new pins in locations, navigating tags, and uploading documents related to pins.

A. GIS Improvement

Modern GIS technology uses digital information by transferring the hard copy of a map into a digital medium, which represents the Earth using various models that include coordinate-related information such as latitude, longitude, and elevation.

B. Dynamic Pin Management: Framework Approach

Dropping a pin is a familiar method to select a point on a map. Dynamic pins (defined by images) are created and mapped to represent the categories or status of their locations, as shown in Fig. 6.

C. Navigation and Viewing Techniques

It is well known that engineering techniques provide vital information for users in the form of text, graphs, pictures, photos, 3-D renderings, and animations. This information plays major roles in decision-making by its users. Fig. 7 presents a typical set of information, which includes a master plan, map, satellite view, and AutoCAD floor plan.

Partial views were used to create, edit, and view suppliers' geographic locations. The mapping functionality was used in several places within the application to reinforce the common map functionality, which was encapsulated within a single partial template for reuse in multiple controllers and views.

The "callback" action handler function is used to add a pin to the map to identify a location. Drag-and-push pin techniques can be used on the map to identify supplier locations, as shown in Fig. 8.

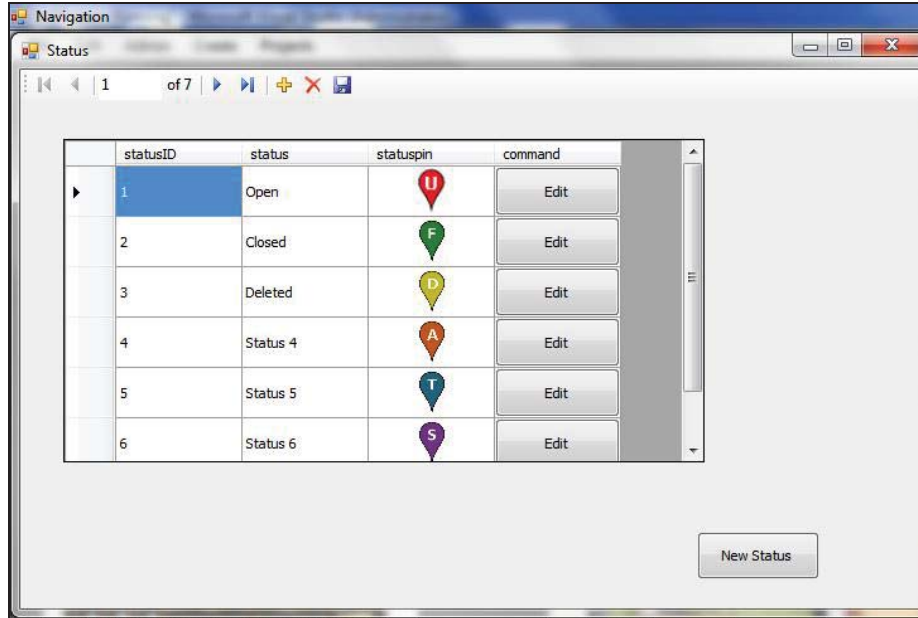


Fig. 6 Model, view, and controller in ASP.NET [19]

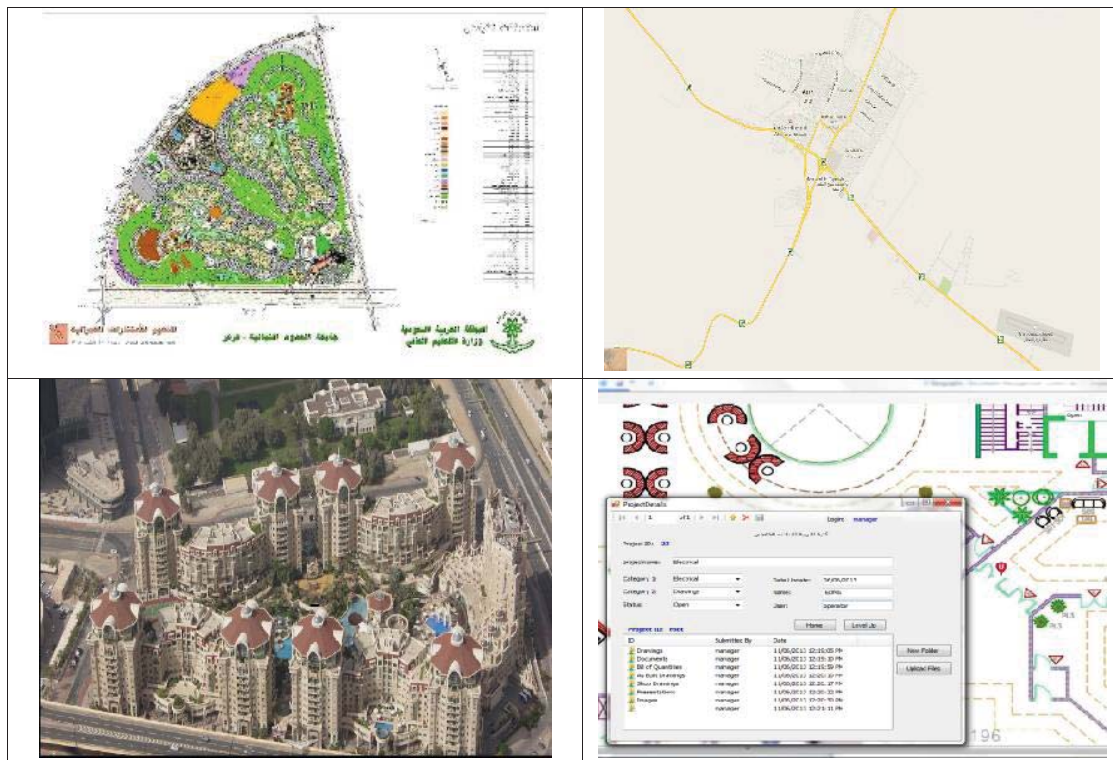


Fig. 7 EDMS presentation of GIS image and drawings

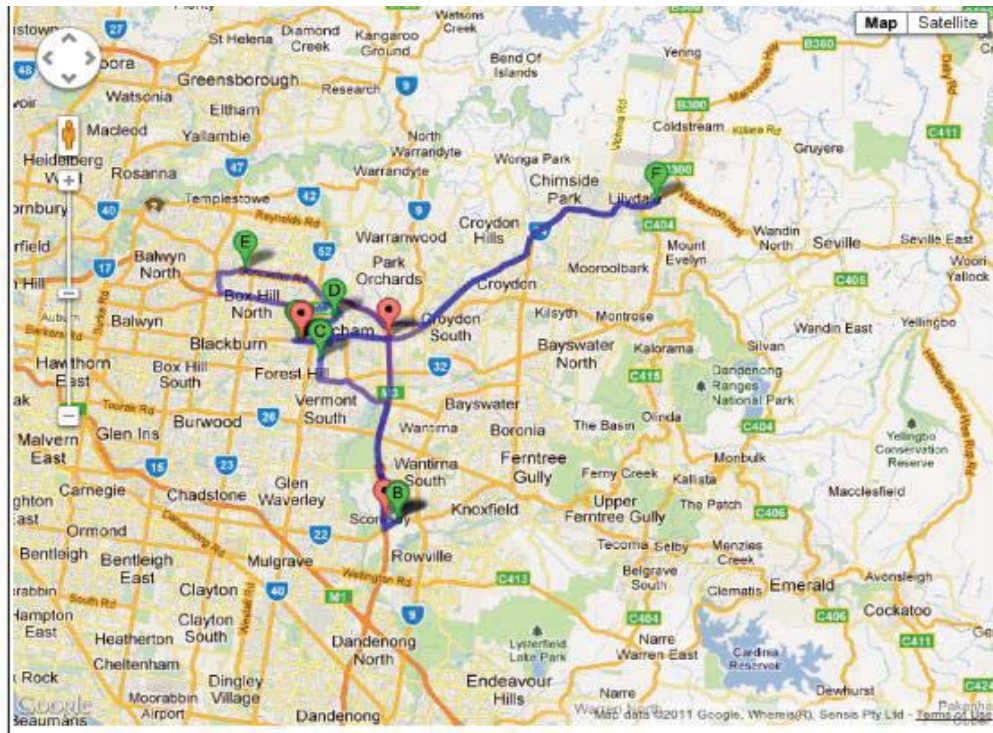


Fig. 8 Map for identifying supplier locations

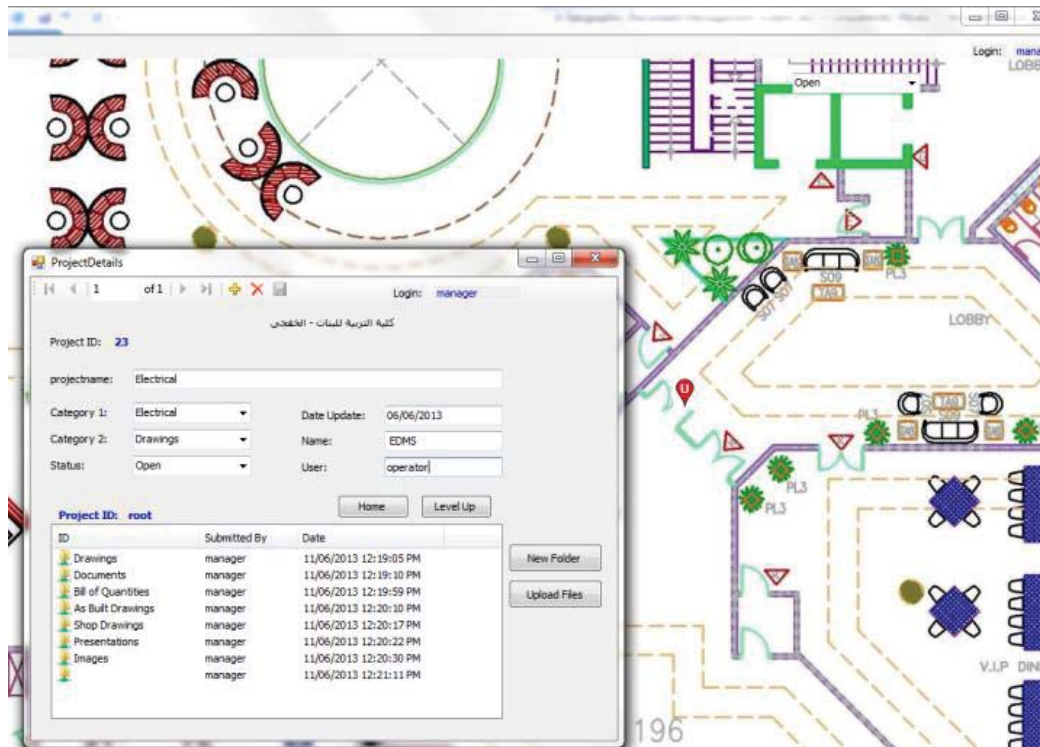


Fig. 9 Management document for a floor plan

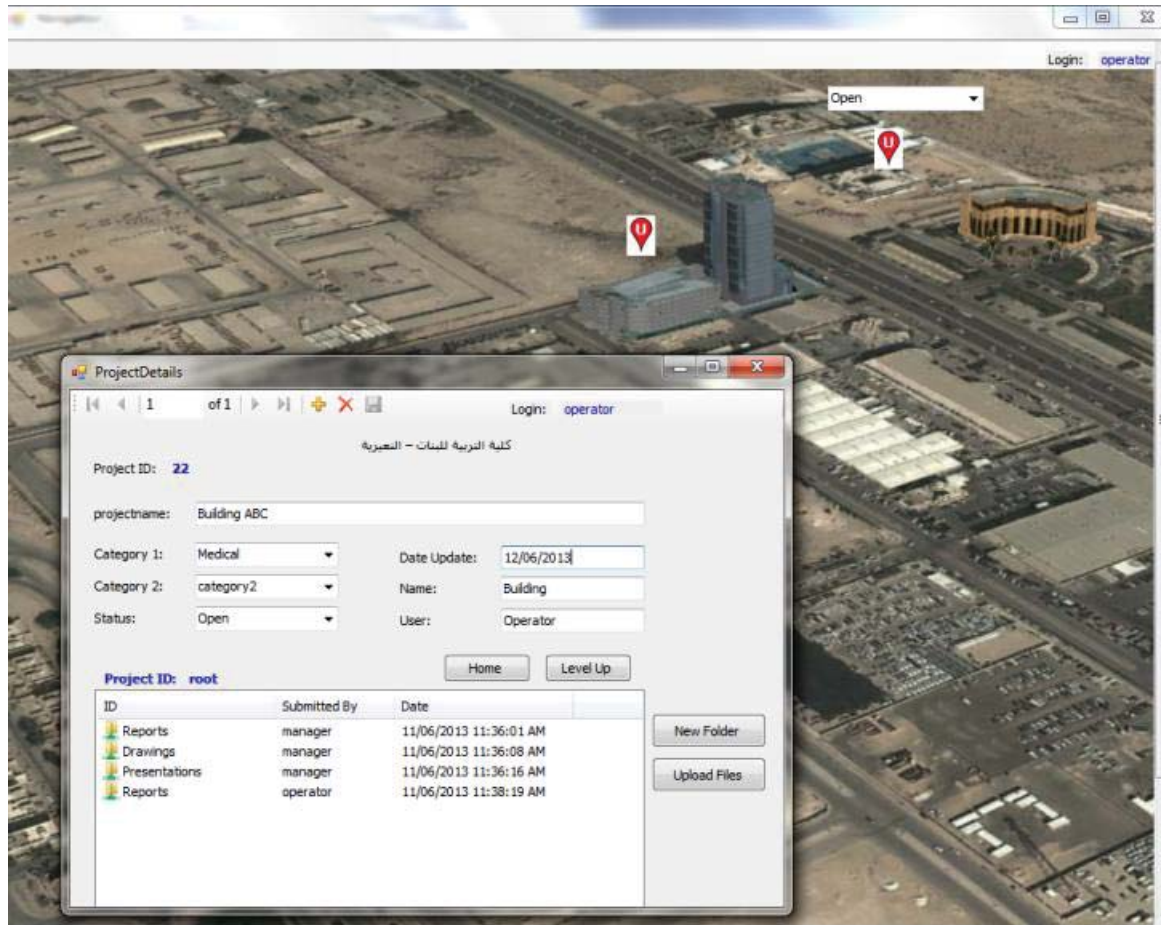


Fig. 10 Linking documents with GIS

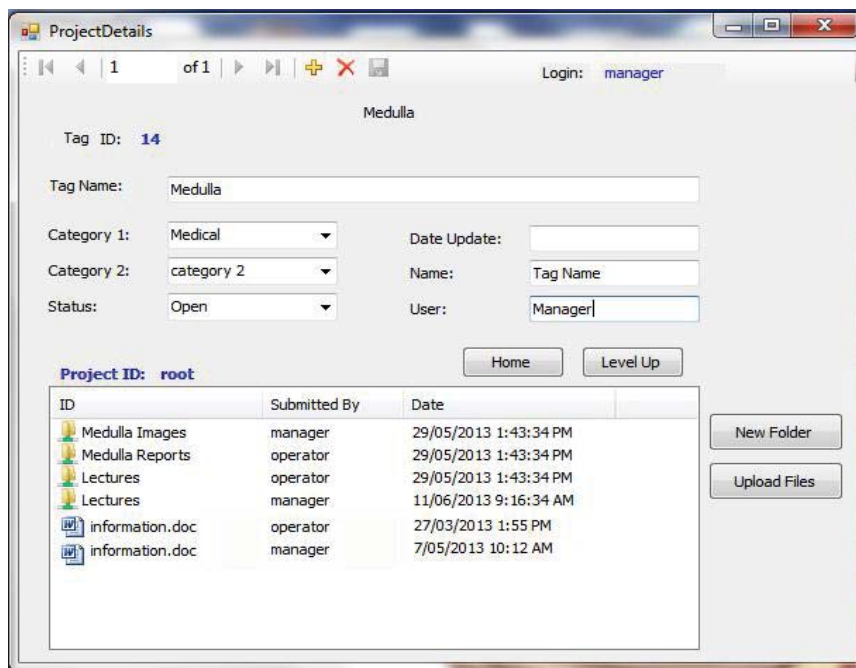


Fig. 11 Vision control procedure.

Other graphic techniques such as AutoCAD can generate drawings for an engineering team by upload and dynamic drag. Tags can be produced for different regions of the drawings. Note that each tag points to a specific location, and therefore users can upload and share drawings or documents related to the selected region. Moreover, tags can be specified that point to a certain space or piece of equipment required by users to manage documents. This type of application, which permits engineers to share documents for a particular region of a specific architectural floor plan, is illustrated in Fig. 9.

The essential information is stored in the database and transferred to the map layer in the form of markers. A window is opened by clicking the mouse to display the relevant documents in particular locations, as shown in Fig. 10.

D. Version Control Procedure

The documents used in this research were stored in the file systems of the remote servers. When creating a new document, a new row is added in the "DocumentTable" that contains an auto-incrementing unique column called "Document ID". The file is renamed with its ID number and saved with the existing file extension, and the actual file name and relation path are stored in the table. This technique is useful to store many documents with the same name in a folder, and several users can create identical files and folders from different user names. Fig. 11 presents folders with the same name stored in a common file location by two different users.

The materials view was generated by using the "Razor" view engine, and the strongly typed view was selected for the model class. The scaffold template was used to create lists and details and for editing and deleting views based on the master layout, where users can select a specific supplier to display the materials that they supply.

E. Final Remarks

This research has demonstrated that geodetic interactive supply chains in the construction industry can be useful in the monitoring movements and storage of materials, the tasks which are essential in construction to ensure that finished products travel from the point of origin to the destination construction site. Meeting the requirements of clients, dealers, suppliers, manufacturers, and service providers is vital for reducing construction costs, minimizing time, and enhancing productivity. The system presented here provides an easy interface to request geo-registered map images from one or more distributed geospatial databases.

An innovative method has been presented to implement Web mapping services and to integrate them with construction SCM systems to generate an interactive GIS for the construction industry. Use of this method in the construction industry would enhance productivity and reduce costs. This study also considered the similarities between medical practice and civil engineering with respect to specific applications that enable development of graphical systems for organizing vital information.

To encourage use of GIS and SCM techniques to reduce costs, save time in the work environment, and achieve better outcomes, this research should be extended in the construction industry.

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