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INTERACTIVE CONSTRUCTION ENGINEERING GIS-BASED ELECTRONIC DOCUMENT MANAGEMENT SYSTEM

Mansour Nasser Jadid

Department of Building Engineering, University of Dammam,
P. O. Box 30973, Alkhobar 31952, Saudi Arabia

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ABSTRACT

Geographic information databases can store, manipulate, and manage geographic data related to the suppliers used by building materials manufacturers. The geodetic supply chain management (SCM) systems used in engineering include all the movements and storage related to materials for works in process and for finished products, ranging from the point of origin to the destination. The availability of these systems is important for the construction industry because they reduce costs and save time, thereby enhancing productivity and effectiveness. This study describes the traditional supply chain model and a proposed geographical information system (GIS)-based SCM that focuses on the implementation of an electronic document management system, which maps the application framework to integrate geodetic support with the supply chain system. This procedure involves guidance to locate the nearest suppliers to satisfy the information requested by project members in different locations. This study also explored the use of GIS-based SCM as collaborative tools in innovative procedures to implement Web mapping services, as well as aspects of their integration by generating an interactive GIS for the construction industry platform.

Keywords: Construction, Coordinate, Document, Geodetic, GIS, Management, Map, Materials, Supply Chain Management, Technology.

1. Introduction

Information technology (IT) provides a platform that facilitates data manipulation in a cost effective and time-saving manner. Dramatic improvements and the rapid spread of IT implementation have been observed in many areas, which have opened new horizons for the developers of software tools and hardware engineering to generate computer programs in various formats [1]. This technology has created opportunities in various fields, e.g., for planners, architectures, engineers, scientists, and medical health workers. In the construction industry, Web-based engineering software needs to be utilized to fully exploit the benefits of IT. A generalized web-based IT system has been designed to improve the collaborations between construction professionals [2], that facilitates Web-based construction project management using tools that are popular in civil engineering.

A traditional electronic document management system (EDMS) was produced for locating documents graphically, which was based on a pilot project that applied groupware and workflow management techniques to civil engineering projects [3]. In this method, the engineering documents comprised monthly reports, general and specific specification documents, drawings, and bill of quantities. These were considered to be integral parts of the project and they were had to be processed in a professional manner.

A decision support system for materials selection during design or construction projects by consultants and clients was also produced [4]. The most important decisions during construction projects are related to the selection of materials. It should be noted that high quality materials are generally recommended after considering that a high initial cost is often offset by reduced maintenance requirements.

Supply chain management (SCM) involves steps that ensure the management of information, materials, and cash flow in a networking of interested parties such as suppliers, consumers, manufacturers, and distributors, thereby reducing costs, saving time, and ensuring that the business quality satisfies customers. Geographical information systems (GIS) rely on mapping technology to locate suppliers, manufactures, and distributors to determine the shortest path to the final destination, and GIS is used as a tool that provides decision support in successful SCM.

2. SCM and GIS

Construction engineering has witnessed an unprecedented boom and it is expanding globally. This has caused materials SCM to evolve over time, there by optimizing production and organizing materials management. Well-known companies have found that it is important to interact with their consumers by using efficient systems when working internationally in a competitive environment. Thus, they use SCM strategies to improve their business performance. Supply chains encompass five main structures: suppliers, manufacturers, dealers, retailers, and consumers, which are also influenced by five factors: information, production, inventory, location, and transportation [5].

Construction planning and execution require the availability of materials on site before activities can commence [6] and conventional supply chain systems lack appropriate planning, which results in material unavailability and extra time required to locate the materials.

A typical construction supply chain for building materials is shown in Fig. (1), which involves the following processes [7].

- The model comprises 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 supply house.
- The supply house delivers the material to the construction site.

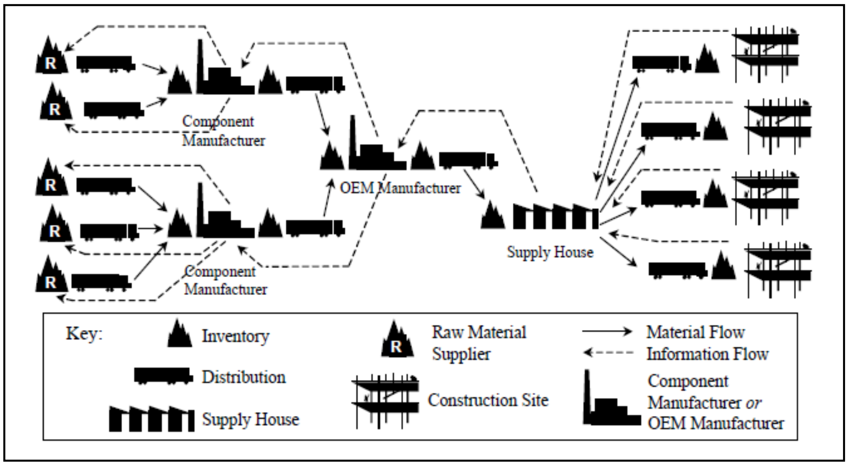

Fig. 1. Construction supply chain for building materials [7].

A network includes multiple organizations [8] where there is a flow of information, such as materials, services, and fund transactions between clients, designers, and other interested parties. This network facilitates the coordination of construction and SCM using an Internet-enabled mechanism can enhance the coordination process.

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 applied in many disciplines, including planning, mapping, engineering, biology, geology, business practice, and health care systems. Infrastructure projects have utilized GIS [9] to deliver a wealth of information, which is accessible via a spatial interface.

GIS has emerged as a challenging technology that allows geographers to incorporate data and methods in various different ways to support conventional forms of geographical analysis [10]. Researchers have also noted the importance of GIS and mapping [11] as decision support systems in business applications.

Figure (2), shows the five main categories of GIS components: people, data, software, hardware, and methods [12, 13].

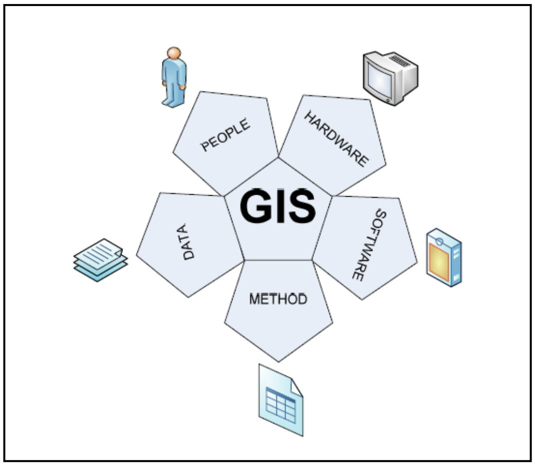

Fig. 2.GIS components [12, 13].

Techniques have been developed for selecting the sites of residential housing by creating a decision support system [14]. A prototype application was developed for a data warehousing technique that allowed investors and other interested developers to select appropriate sites by ranked ordering based on a list of availability. This technique used GIS software at the back-end and the analytic hierarchy process in the front-end. Figure (3) shows a logical model developed for site selection.

GIS has been implemented in health care systems and used in health research [15] where it can provide a spatial dimension, as well as providing a tool for health applications and services. A simple illustration of the layers provided by GIS is presented in Fig. (4). Basic applications include the construction of disease maps, analyzing trends in space and time, and mapping populations at risk. In general, research has concentrated on obesity trends between 1985 and 2007, and other diseases in the USA.

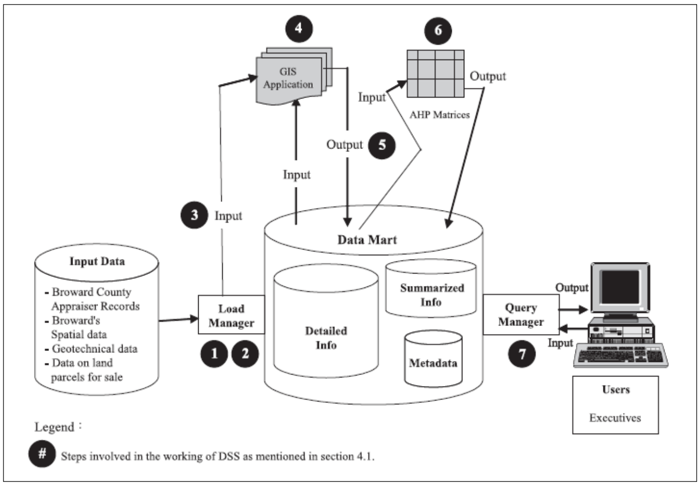

Fig. 3.Conceptual model of a decision support system [14].

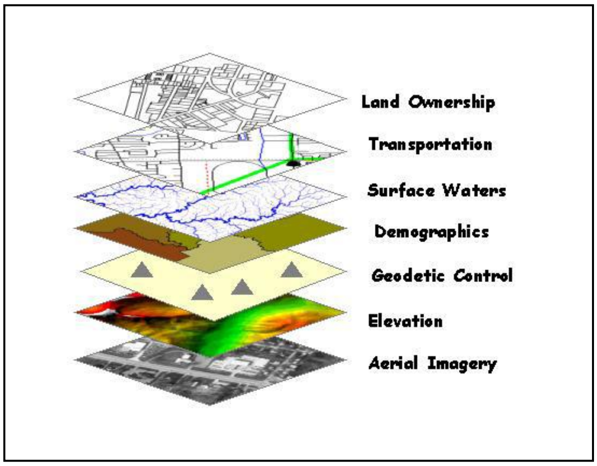

Fig. 4. Different types of layers provided by GIS [15].

A framework was developed based on the use of GIS for construction SCM, which incorporated Web mapping services to enhance the supply chain process [16]. The proposed system involved the following.

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

3. Component-based construction

IT and computer engineering have well-defined roles in the construction industry and in medical practice. Construction projects and medical practices have some similarities in terms of their function and operation, and both are as 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 the storage and retrieval of information 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 future use. Software engineering also includes many components that can be used in a variety of products, such as the creation of graphical windows, software applications, and interaction methods. In general, the build or design of software involves logical processing rather than a mechanical product. For example, an interactive visualization geodetic system was designed for collecting hurricane data from 1851 to 2009, which supports data exploration from three linked perspectives: spatial, temporal, and multidimensional [17].

4. Application development process

In the present 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), which was used because its syntax is compact and this reduces the need for typing [18]. ASP.NET is implemented as a model, view, and controller (MVC) combination, which is an architecture that allows scalable and standard-based web applications to be constructed, as follows.

1. Models are classes that manipulate data.
2. Views are web pages included in the web application.
3. Controllers are components that can handle interactions with the user.

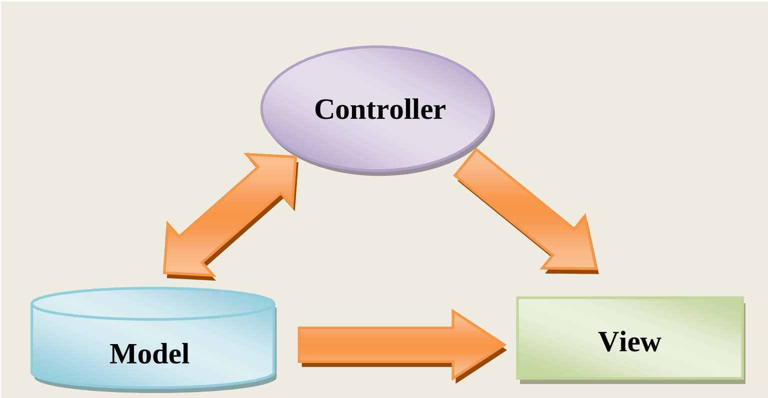

Fig. 5. Model, view, and controller in ASP.NET [18].

4.1. Database normalization and self-organizing trees

In database normalization, there are one-to-many relationships between *"LocationTable* and *PinsTable"* and *"Pins Table* and *DocumentTable"* which indicates that each location has multiple pins and thateach pin can store multiple documents. Similarly, the "*UserTable"* has dual one-to-many relationships between *"PinsTable"* and "*DocumentTable."* The *"LocationTable"* has foreign key relationships between its columns: *"ParentID"* and *"LocationID."* This is shown as a bounded region in the table in Fig (6). A similar internal foreign key relation is shown in the "*DocumentTable."* The internal foreign key relationship shows that the locations or documents have one-to-many relationships between *"LocationID"* and *"documented"* with *"ParentID."* This function is important for linking the nodes to their parents and for maintaining the hierarchy of the locations and documents.

In self-organizing trees and GIS implementations, each location is divided into sublocations, which are linked to their parent's location. The hierarchy of locations, pins, and documents is shown in Fig. (7), where the location node comprises locations "A," "B," "C," and "D" while location "A" is the parent of location "D." This indicates that one location can have many locations. Furthermore, each of the locations can also be linked to multiple pins. For example, location "B" is linked to three pins: "A," "B," and "C," but none of these pins have sub-pins. Similarly, pin "B" is linked to documents "A," "B," "C," and "D" through folder node where document "A" is the parent of "D."

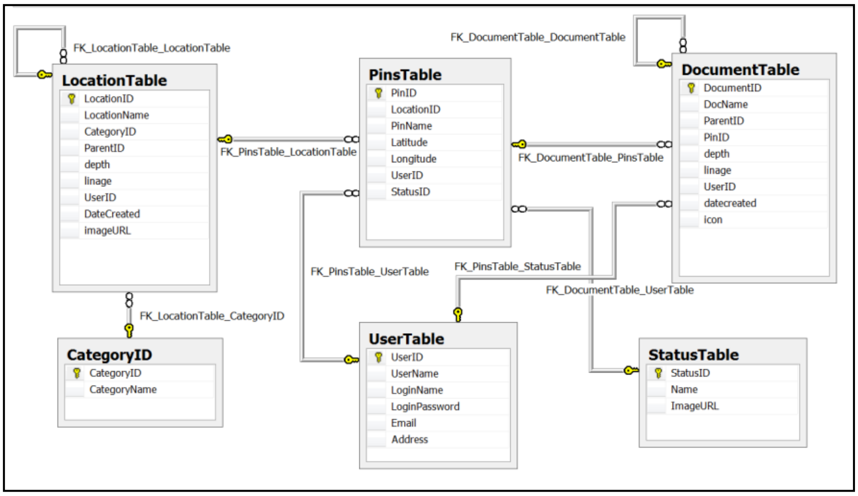

Fig. 6. Diagram showing the database relationship.

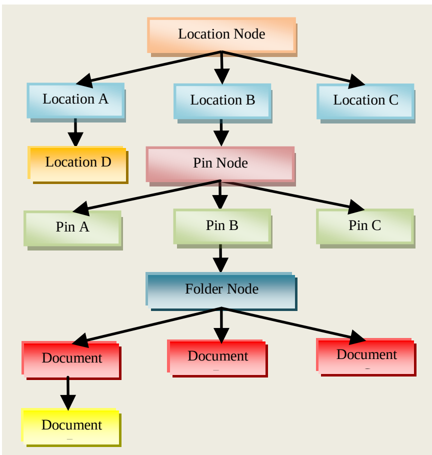

Fig. 7. Sample of the self-organizing trees.

It should be noted that the multi-level hierarchy exists only in the location and document, where there are no internal relationships among the pins, which implies that there are no sub-pins of a pin. As a result, the self-organizing trees are focused on locations and document tables. Table (1) shows the tree data for the location table.

Table 1.
Tree data for the location table

ID	Parent-Id	Name	Depth	Lineage
1	NULL	Root Node	0	/1/
2	1	Child A	1	/1/2/
3	1	Child B	1	/1/3/
4	1	Child C	1	/1/4/
5	2	Child D	2	/1/2/5/

5. Geo-Location interactivity application

Geological interactivity was added to the application using web mapping application programming interfaces (APIs), which were implemented to create interactive mapping applications that provide features for customizing the map. The overlays, controls, and services are API functions, which are used in this application for calculating the distances between multiple destinations in order to locate the nearest destination [19]. This facilitates the visual tracking of the locations of suppliers and the site for which the evaluation of the materials has been requested. The geo-location API defines a high-level interface for location information, which is only associated with the device implementation hosting, such as latitude and longitude [20]. The code was written to retrieve the latitude and longitude coordinates from the position argument of a Show Map Method. The geographic position information is provided in terms of World Geodetic System coordinates [21], where a Map object was created with the position, records, center, map type, and zoom level. The steps required to create the location, pins and uploading are as follows:

1. Navigating and creating locations.
2. Adding new pins in locations.
3. Navigating tags.
4. Uploading documents related to pins.

5.1. Development of the GIS

GIS [22] has been implemented in many disciplines using the new world geodetic system, [20] which is well documented throughout the world. Modern GIS technology uses digital information by transferring the hard copy of a map into a digital medium, which represents the Earth with various models that include information related to coordinates such as the latitude, longitude, and elevation.

5.2. Dynamic pin management

Dropping a pin is a familiar method for selecting a place on a map. Dynamic pins are created and mapped to represent the categories or status of the locations (images define these pins), as shown in Fig. (8).

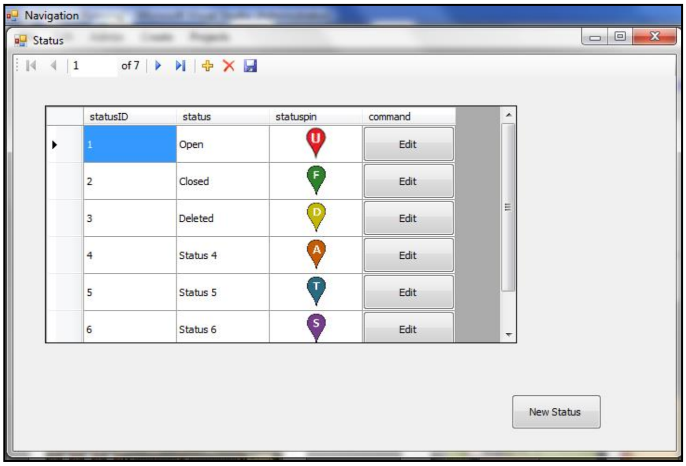

Fig. 8. Dynamic pin management.

5.3. Views navigation technique

Engineering applications provide vital information for users in the form of text, graphs, pictures, photos, 3-D renderings, animations, etc. This information has major roles in decision-making by these users. Figure (9) shows typical information, including a master plan, map, satellite view, and AutoCAD floor plan.

Partial views were implemented for creating, editing, or viewing the geographic locations of the suppliers, where the mapping functionality was utilized in several places within the application to reinforce the common map functionality, which was encapsulated within a single partial template forreuse 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 applied on the map to identify the locations of suppliers, as shown in Fig. (10).

Fig. 9.EDMS presentation of GIS, and drawings.

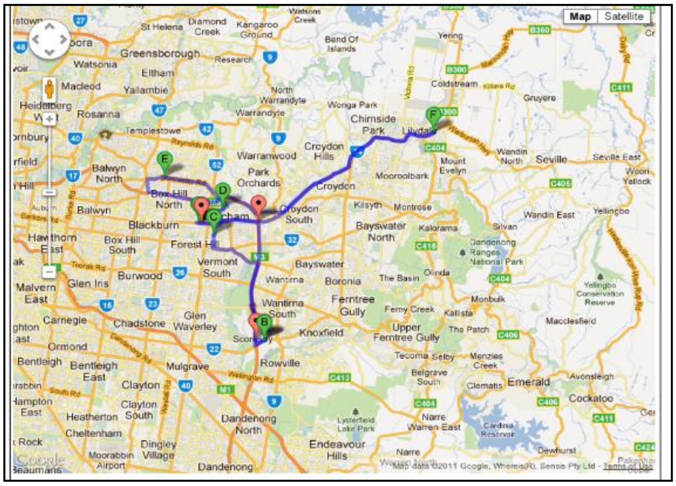

Fig. 10. Map to identify the locations of suppliers.

AutoCAD or other methods can generate drawings based on teamwork in the engineering office via upload and dynamic drag, where tags can be produced for different regions of the drawings. It should be noted that each of the tags points to a specific location so users can upload and share drawings or documents related to the selected region. In addition, it is possible to specify tags that point to a certain space/equipment required by users to manage the documents that can be handled. This type of application is shown in Fig. (11), which allows engineers to share documents for a particular region ofthe selected architectural floor plan.

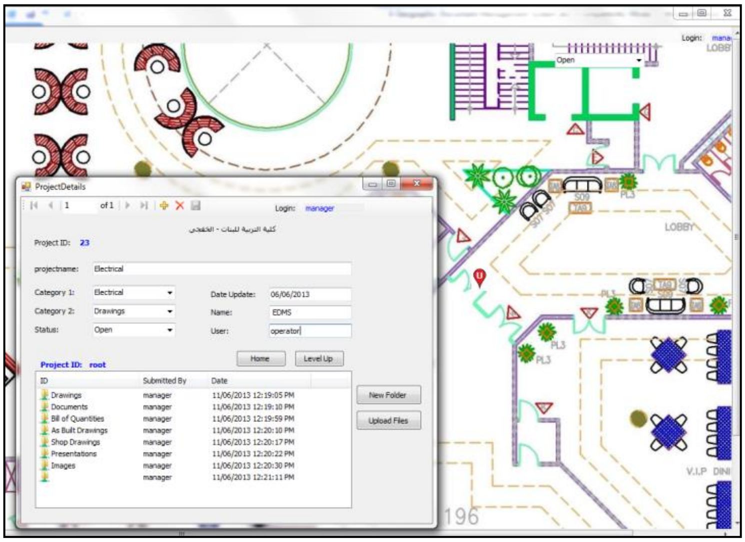

Fig. 11. Document management for a floor plan.

The requisite information is stored in the database and transferred to the map layer in the form of markers, where a window is opened by clicking the mouse to display the relevant documents in particular locations, as shown in Fig. (12).

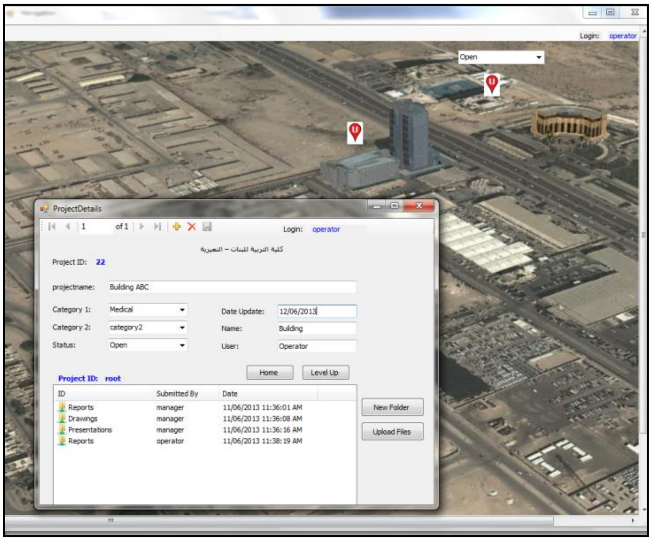

Fig. 12. Documents link with GIS.

5.4. Version control procedure

The documents are stored in the file systems of the remote servers. A new row is appended in the *"DocumentTable"* when creating a new document that contains an auto-increment unique column "*Document ID*." The file is renamed with its ID number and saved with the existing file extension, while the actual file name and relation path is stored in the table. This procedure is useful for storing multiple documents with the same name in a folder and multiple users can create identical files and folders from different user names. Figure (13) shows folders with the same name stored in a common file location by two different users.

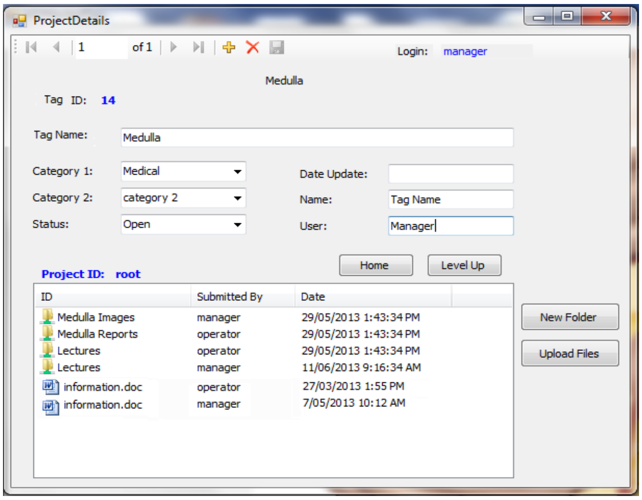

Fig. 13. Version control procedure.

The material view was created 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 particular supplier to display the materials they are supplying.

6. Conclusions

The use of geodetic interactive supply chains in construction can monitor the movements and storage of materials, and these types of application are useful in the construction process for ensuring that finished products travel from the point of origin to the construction destination site. Meeting the requirements of clients, dealers, suppliers, manufacturers, and service providers is vital for reducing construction costs, minimizing time, and enhancing productivity. The proposed system provides an easy interface for requesting geo-registered map images from one or more distributed geospatial databases.

This study provides an innovative method for implementing Web mapping services and their integration with construction SCM systems to generate an interactive GIS for the construction industry. The application 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 allow the development of graphical systems for organizing vital information.

Further research is required in the construction industry to determine the benefits of this technique in more depth. It is necessary to encourage the use of GIS and SCM techniques to reduce costs, save time in the work environment, and achieve better outcomes.

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نظام إدارة الوثائق الالكترونية التفاعلي لهندسة التشييدالمبني على قاعدة نظم المعلومات الجغرافية

الملخص العربي

ان قواعد بيانات المعلومات الجغرافية لديها القدرة على تخزينوإدارة البيانات الجغرافية المتعلقة بالموردين المستخدمة من قبل الشركات المصنعة لمواد البناء . وتشمل أنظمة الجيودسية في إدارة سلسلة الامداد (SCM) المستخدمة في الهندسة جميع الأنشطة لتخزين المواد المتعلقة للعمل في عملية المنتج النهائي ، ابتداء من نقطة البداية إلى وجهة النهاية. إن توفر هذه النظم مهم لصناعة البناء والتشييد لتخفيض التكاليف وتوفير الوقت ، وبالتالي تعزز الإنتاجية والفعالية. وتوضح هذه الدراسة نموذج سلسلة الامداد التقليدية ونظام المعلومات الجغرافية المقترحة (GIS) لتعزز سلسلة الامداد لتنفيذ نظام إدارة الوثائق الإلكترونية ، التي تقوم بتعيين إطار تطبيقي لدمج الدعم الجيودسية مع نظام سلسلة المداد. ويشمل هذا الإجراء تحديد موقع أقرب الموردين لتلبية المعلومات من قبل العاملين بالمشروع المطلوب في عدة مواقع مختلفة. كما ان هذه الدراسة تسعى لاستكشاف استخدام إدارة سلسلة الامداد المبنية على نظم المعلومات الجغرافية كأدوات في إجراءات تعاونية مبتكرة لتنفيذ خدمات الخرائط العنكبوتية، فضلا عن جوانب التكامل من خلال إيجاد نظم المعلومات الجغرافية التفاعلية لصناعة البناء والتشييد الاساسي.