

# A Geographic Interactive Supply Chain Management System for Construction Projects

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**Abstract**— The diversity of the construction industry, its range of specialized services, and the requirements of its numerous participants make it one of the most complex industries. This paper presents a framework to implement a geographic information system (GIS) in construction supply chain management (SCM) incorporating web mapping services to enhance the supply chain process. The proposed system is helpful in locating the nearest suppliers when selecting a particular material needed for construction. The first part of the paper presents information about the traditional supply chain model and compares this with the proposed GIS based SCM. The second part focuses on implementing a web based mapping application and a framework to integrate geodetic support to the traditional supply chain system. This process is a guide to locating the nearest suppliers and provides the ability to feed the information required to the project participants in different locations. A geographic information database is generated that has the ability to store, manipulate, and manage the geographical data of the suppliers manufacturing the building materials. Geodetic supply chain management systems in engineering cover all movements and storage of materials for work in process recording, and for finished products, from the point of origin to the construction site.

**Index Terms**— Construction, Database, Geographic Information System, Model View Controller, Materials, Supply Chain Management, Supplier, Web based

## I. INTRODUCTION

THE construction industry is expanding globally and this has caused materials supply chain management (SCM) to evolve over time to optimize production and materials management. The geographic location of materials suppliers and their distance from the construction site are factors that have a significant effect on the cost and quality of the construction. An integrated coordination mechanism is required for successful SCM. In 2007, Xue [1] suggested a coordination mechanism for construction SCM that uses an internet enabled mechanism to enhance the coordination process. The construction industry has been slower than other industries to employ the concept, perhaps because of the unique context in which SCM collaboration was applied [2]. SCM involves challenges such as developing trust and collaboration among supply chain partners and identifying best practices that can facilitate supply chain process

alignment and integration [3].

Geographic information systems (GIS) are linked to many disciplines, including engineering, planning, and analysis. They have also been applied in business domains and industries. GISs have emerged as very powerful technologies because they allow geographers to integrate their data and methods in ways that support traditional forms of geographical analysis [4]. In order to further enhance the supply chain process in construction, the authors integrated GIS with SCM for construction materials and suppliers. Li, *et al.* [5] developed an internet based GIS for an e-commerce application to assist in the search for materials information in specific geographic regions of China. This paper illustrates the implementation of web mapping services and aspects of their integration with construction supply chain management systems and generate an interactive GIS for the construction industry.

The suggested system provides a simple interface for requesting geo-registered map images from one or more distributed geospatial databases. The interface is developed in Visual Studio and Model-View-Controller is used to create interfaces for mobile and handheld devices. The map is integrated in the application using Asynchronous JavaScript and XML (AJAX) and the JavaScript Object Notation (JSON) format has been used to serialize and transmit the structured data. A utility library has been created to interact with Virtual Earth and display a map with location markers. The geolocation system is used with Modernizr and Yepnope to determine the geographic location of the users from their IP addresses. The geospatial features of SQL Server are implemented to perform a location-based radius search. The overlay objects are tied to the latitude and longitude coordinates to display markers and relevant information on the map.

## II. SUPPLY CHAIN IN CONSTRUCTION AND SELECTION APPROACH

Traditional SCM has no effective mechanism for locating the nearest supplier for particular materials. High quality materials are generally recommended after taking into consideration the fact that a high initial cost is often offset by reduced maintenance requirements. In 2012, Jadid and Badrah [6] implemented a decision support system for materials selection for projects under design or construction by consultants and owners. The research conducted on SCM in the construction industry is not well documented. Taylor and Bjornsson [7], illustrated that a myopic view of supply chains leads to sub-optimization; a holistic view of supply chain interactions allows for the evaluation of the overall performance of materials handling, distribution, and

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information flow through every link of the chain. A traditional model for a supply chain in construction is shown in Fig. 1.

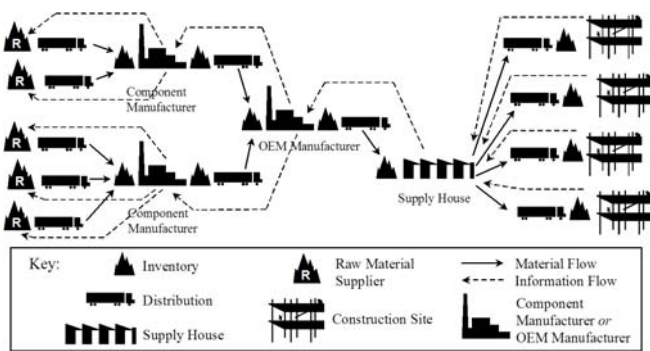


Fig. 1. Traditional Construction Supply Chain for Building Material [7].

Materials supply chain selections are linked with project planning; selections should be considered during project planning and scheduling. To obtain effective tools for planning and scheduling, research on supply chain management can be broadly classified into three categories, namely; operational, design, and strategic. Although many analytical and numerical models have been proposed to handle operational and design issues, it is important to ensure that the required materials are available on time at the site before the execution of related activities [8]. In the traditional supply chain system many material items may not be available and may need time to locate; ultimately, the materials may need to be imported, which requires extra time and might result in cost increases.

### III. GEODETIC SUPPLY CHAIN MODEL

Our suggested system provides a simple interface for requesting geo-registered map images from one or more distributed geospatial databases. The code is written to control shapes and layers on the maps. The response to a request is one or more geo-registered map images displayed in the browser application. A geodetic system has already been designed for interactive visualization of hurricane data that supports data exploration on three linked perspectives: spatial, temporal and multi-dimensional [9]. The proposed system, as shown in Fig. 2, is integrated and the sub-system components are interlinked with the supplier geographic data and the web mapping service. Evaluations could be submitted by the end users as referrals to the materials for particular suppliers.

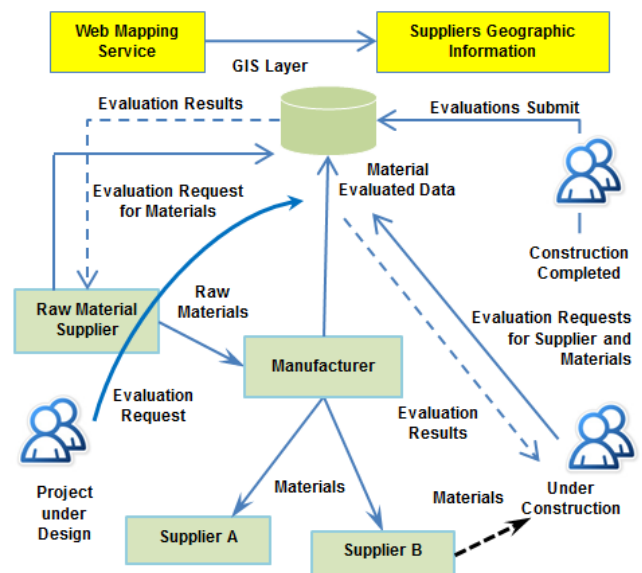


Fig. 2. Construction SCM with Geographic Support

It is evident from Fig. 2 that the manufacturer entities are linked to supplier entities. Similarly, the supplier entity has some relation with the materials entity. The material entities should be available to the evaluation entities so that users would be able to perform and submit the evaluations about a specific material or supplier. To create any of these entities a user entity is required and, for a particular supplier, if a materials entity exists, the supplier data could not be removed. The suggested supply chain system addresses an effective mechanism for these relations among these entities. Some of the advantages of the suggested geodetic system are as follows:

- 1) Suppliers: The nearest supplier of a particular material in a particular geographic area can be located.
- 2) Materials: Materials can be selected on the basis of evaluations submitted by other users; this can help to identify blacklisted materials and suppliers.
- 3) Manufacturer: A manufacturer and suppliers for materials/products of a particular brand can be found.
- 4) Evaluations: The evaluations of materials, as well as the related site locations, can be stored and retrieved

### IV. APPLICATION DEVELOPMENT

The application is created in ASP.NET C# using Visual Studio and SQL Server. The Model-View-Controller Version 3 is used to enable desktop and mobile views for a single application [10]. The Razor is used as a view engine because its syntax is compact and reduces typing. The packages used in the application are shown in Appendix A.

#### A. Model-View-Controller

The views and models use the publish-subscribe protocol; when model data is changed, it will update the view. It allows us to attach multiple views to the same model [11]. A general concept of an MVC model is shown in Fig. 3. The controller interprets inputs from the user, informs the model and/or the view to change as appropriate, and the view handles the display of information.

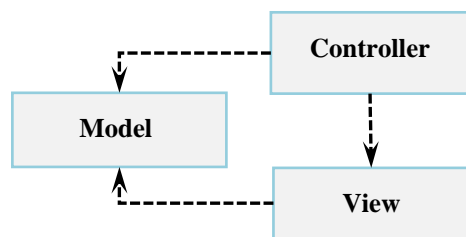


Fig. 3: The MVC Model [MSDN]

### B. Entity Framework (EF)

There are several ways of working with data in the Entity Framework (EF): Database First, Model First, and Code First. When using the Database First approach, if the database is already created, the EF automatically generates a data model that consists of classes and properties. With Code First, the mapping between the stored schema and the model is represented by the code. A conceptual entity data model is shown in Fig. 4.

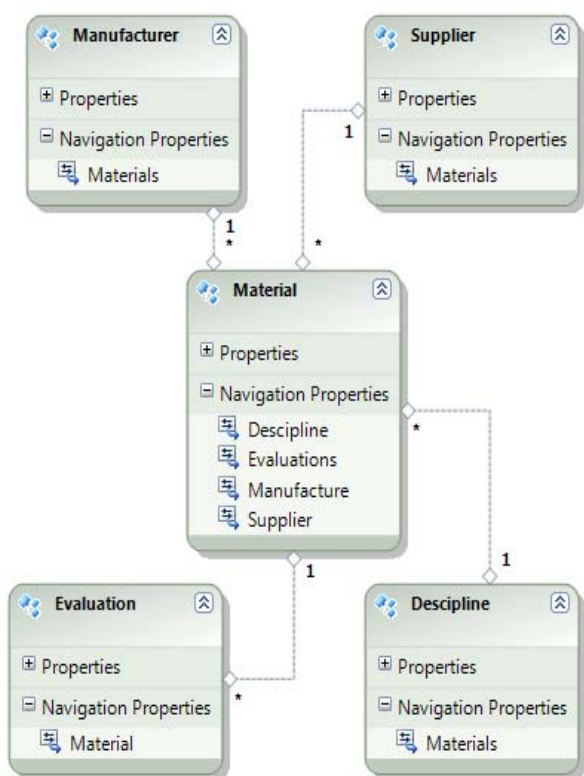


Fig. 4: Class Diagram: Entity Data Model

### C. The Model Classes

The model classes, namely Manufacture, Supplier, Discipline, and Material are created in the Model Folder. An ICollection interface in the Supplier class that manipulates generic collections is used to navigate an association or relationship between two entities. Material property on the Supplier class has a navigation property shown in Appendix B.

### D. Database Context Class

The DbContext is created in the DAL folder to provide coordination between the data and the model. DbContext is

usually used with a derived type that contains DbSet<TEntity> properties for the root entities of the model. The derived MaterialDbContext class declaring the DbContexts for all of the model classes is shown in Appendix C.

The\_INITIALIZER class is created for generating the database when required and it loads test data into the new database. A connection string is also required to be set in the Web.Config.

### E. Controllers and Views

The controllers are created employing a scaffolding template "read, write, actions, and views" using Razor view and the MaterialDbContext. The controller is responsible for controlling how a user interacts with an MVC application. The database is automatically created using the initialized data on the first run of the application. There is a one-to-many relationship between supplier and materials. The material view is created using the Razor view engine and the strongly-typed view is selected for the model class. The scaffold template is used for creating list, details, edit, and delete views based on the master layout. As shown in Fig. 5, users are able to select a particular supplier to display the materials they are supplying. Selecting a particular material displays the evaluations of the material that were submitted by the users.

Suppliers					
<a href="#">Create New</a>					
ID	Name	Description	Phone	Website	Email
<a href="#">Select</a>	<a href="#">Edit</a>	<a href="#">Details</a>	<a href="#">Delete</a>	Supplier-1	Description-1 phone-1 website-1 email-1
<a href="#">Select</a>	<a href="#">Edit</a>	<a href="#">Details</a>	<a href="#">Delete</a>	Supplier-2	Description-2 phone-2 website-2 washington
Material Supplied by Selected Supplier					
	Material ID	Material Name	Description	Manufacturer	Discipline
<a href="#">Select</a>	1	Material-1	Material Description -1	Manufacture-1	CSI-1
<a href="#">Select</a>	2	Material-3	Material Description -3	Manufacture-1	CSI-1
<a href="#">Select</a>	3	Material-2	Material Description -2	Manufacture-2	CSI-2

Fig. 5: The Material View of Suppliers

In order to add the authorization logic, the [Authorize] filter attribute is added to the Create action method that enables a user to register before submitting their data.

### V. GEOLOCATION INTERACTIVITY

The geological interactivity is added to the application using web mapping APIs. These APIs are used to create interactive map applications and provide features to customize the map. The overlays, controls, and services are the API functions used in this application. A similar project is implemented for calculating distances between multiple destinations and locating the nearest destination [12]. This enables the visual tracking of the locations of the suppliers and the site for which the evaluation of the materials has been submitted. The Geolocation API defines a high-level interface to location information associated only with the device hosting the implementation, such as latitude and longitude [13]. The code was written to retrieve the latitude and longitude coordinates from the position argument of a ShowMap Method. An instance of a Map object was created with the position, credentials, center, map type, and

zoom level. The geographic position information is provided in terms of World Geodetic System coordinates [14].

#### A. GIS Development

The Geographic information system can be implemented in many disciplines [15]. The newer World Geodetic System, 1984 (WGS84) works well around the world [16]. Modern GIS technologies use digital information by transferring the hard copy of a map into a digital medium. The earth can be represented by various models that contain information on coordinates (e.g., latitude, longitude, elevation).

#### B. WC3 Geographic Support

Location aware applications are becoming more important. The geolocation feature is added using the Yepnope.js and Modernizr [17]. Yepnope.js is an asynchronous resource loader that can load scripts based on the outcome of some condition and the Modernizr detects a web browser's ability. First, the resource loader tests if the browser supports native geolocation. The overall functionality is shown in Fig. 6. If the browser supports geolocation, it gets the current location of the user and set the map to that location.

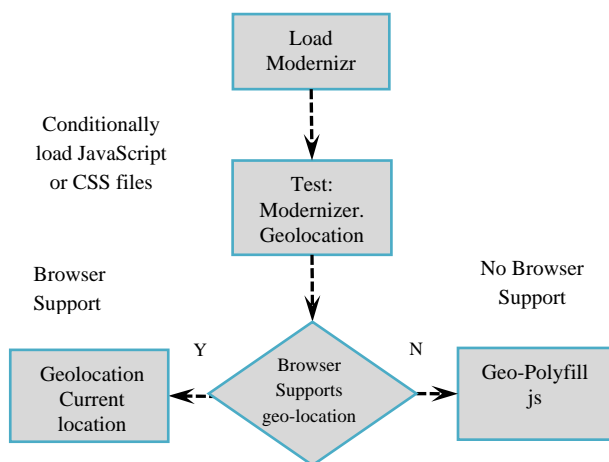


Fig. 6: Modernizr for Geolocation

#### C. Map Partial Views

Partial views are used to create, edit, or view the geographic locations of the suppliers. The mapping functionality is utilized in several places within the application; therefore the common map functionality has been encapsulated within a single partial template to reuse in multiple controllers and views. The callback event handler function is used; this adds a pin to the map for location identification. Draggable pushpins are used on the map for location identification of suppliers, as shown in Fig. 7.

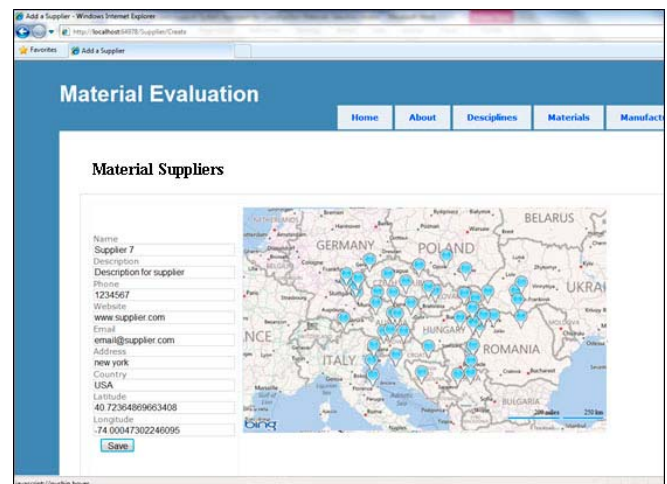


Fig. 7: Supplier's Markers on Map Overlay

The related information is stored in a database; relevant information is passed to the map and appears on the info window on the Mouse Click event on the Markers, as shown in Fig. 8.

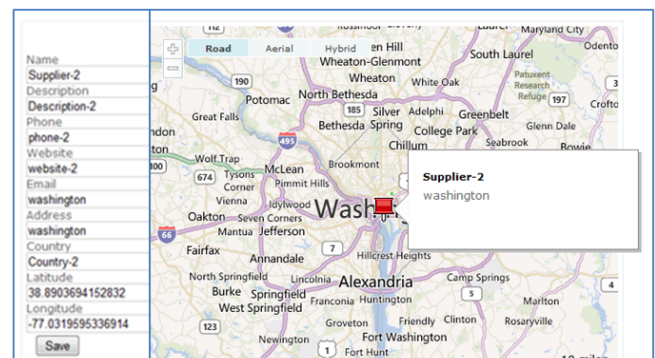


Fig. 8: Sending Supplier Data to the Map

The geographic locations of suppliers are stored in the SQL table with latitude and longitude values received from the maps. The sample data is shown in Fig. 9 for some suppliers.

#### Suppliers

[Create New](#)

ID	Name	City	Country	Latitude	Longitude
<a href="#">Select</a>	Supplier-1	tokyo	Country-1	35.6832084655762	139.808944702148
<a href="#">Select</a>	Supplier-2	paris	Country-2	48.8569297790527	2.34120011329651
<a href="#">Select</a>	Supplier 3	japan	japan	35.1559982299805	136.059997558594
<a href="#">Select</a>	Supplier 4	newyork	US	40.7145500183105	-74.0071182250977
<a href="#">Select</a>	Supplier 8	italy	country	42.7680015563965	12.4919996261597
<a href="#">Select</a>	supplier 9	dehli	india	28.6143398284912	77.2121887207031
<a href="#">Select</a>	supplier 10	karachi	pakistan	24.9267101287842	67.0343704223633
<a href="#">Select</a>	supplier 11	london	uk	51.5063209533691	-0.127140000462532

Fig. 9: Suppliers Geolocation Data

## VI. CONCLUSION

Geodetic supply chain management in engineering covers all movements and storage of materials for work in process recording, and for finished products, from the point of origin to the construction site. Those involved in facilitating the requirements include suppliers, customers, manufacturers, and those providing services, transportation,



and storage. All this requires the use of information technology to facilitate the information flows that are required to manage a supply chain efficiently and to achieve the project completion timetable. The benefits of such systems are visible in other disciplines and have been researched and implemented in those other disciplines; applying this technology to the construction industry would be effective, would enhance the industry's productivity, and would reduce costs. The benefits of the proposed systems are vital for the construction industry; they would be effective and enhance its productivity.

## APPENDIX

### Appendix A. List of Packages

TABLE A: LIST OF PACKAGES

Package Name	Version
jQuery	1.5.1
jQuery.vsdoc	1.5.1
jQuery.Validation	1.8.0
EntityFramework	4.1.10331.0
Modernizr	1.7
PagedList	1.14

### Appendix B. Supplier Class Declaration

```
public class Supplier
{
    [HiddenInput(DisplayValue = false)]
    public int SupplierID { get; set; }
    public string Name { get; set; }
    public string Address { get; set; }
    public double Latitude { get; set; }
    public virtual ICollection<Material> Materials { get; set; } }
}
```

### Appendix C. Material Class Declaration

```
public class MaterialDbContext : DbContext
{
    public DbSet<Supplier> Suppliers { get; set; }
    public DbSet<Discipline> Disciplines { get; set; }
    public DbSet<Manufacture> Manufactures { get; set; }
    public DbSet<Material> Materials { get; set; } }
}
```

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