DEVELOPMENT OF A WEB-BASED DECISION SUPPORT SYSTEM FOR MATERIALS SELECTION IN CONSTRUCTION ENGINEERING

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ABSTRACT

The rapid advance of information technology, especially in Internet and Web-based technologies, in recent years has encouraged the development and integration of various technologies for a number of application domains, mainly in architecture, engineering, construction, and other disciplines. This paper develops a framework using a Web-based system inside a materials selection decision support system for projects under design or construction. In addition, the paper focuses on automating the materials selection process using a Web-based approach to make information available to project participants in different locations. The proposed system includes database and decision support components that effectively handle materials approval, selection criteria, and materials information management. The building materials database can store, manipulate, and manage data on suppliers and manufacturers which can be used for evaluation. This building materials database provides information to the decision support components. The proposed decision support component relies on the quantitative methods of value engineering. The construction process must consider various kinds of materials because materials selection is significant for cost control as well as for the environment. To select the right materials and to avoid delays in project completion, all parties should possess and manage applicable knowledge from many disciplines.

Keywords: Construction, Decision, Development, Materials, Selection, Web-based, Support system.
1. INTRODUCTION

Materials selection is an essential activity early in the engineering design consultant stage and during the construction process. This process starts at the beginning of the design stage and affects the function of the designed part as well as the cost of the final product. It is important for the designer consultant to consider materials selection in the early conceptual design stage to generate the necessary tender documents. Integrating decision support ideas and Web-based applications into materials selection for projects under design or construction is essential to support a collaborative creation and management environment. Web-based application and decision support concepts have been integrated to develop an efficient Web application for prequalification tendering processes.

The construction industry is one of the largest and most complex industries, involving many participants and several phases and requiring a diverse range of knowledge and specialized services. In this environment, it is not easy to control and manage construction projects effectively. The construction industry is expanding globally and therefore requires a Web-based decision support system so that it can evolve over time and be managed effectively. High quality materials are generally recommended because high initial cost is often offset by reduced maintenance requirements.

A Web-based system is proposed for an online materials and supplier database that could be used by consultants, supervisors, and clients to select appropriate materials and suppliers. Using a Web-based approach for the database incorporated in the proposed materials selection decision support system makes it possible to provide information to project participants in different locations. The issues of materials approval, selection, and information management are the main focus of this paper. Wide participation is needed to update the sources of information to feed into a materials selection decision support system. Wang [1] evaluated the intensity of construction land use using the Delphi method combined with qualitative and quantitative analysis and an evaluation index system. Quantitative decision support systems have been applied in a wide variety of disciplines. El-Gafy et al. [2] developed a decision support system for evaluating groundwater quality and managing water use. It identified water quality problems and their impact for the benefit of the public and of specialist and non-specialist decision makers. Another study by Lee et al. [3] proposed a decision support system for a large apartment building project in which the clients could make cost-based decisions that met requirements, while the builders controlled both resource planning and interior design construction costs. A computer-aided material selection system for aircraft design using a Web-based interface was introduced by Lan et al. [4] by applying a materials selection strategy that combined screening and ranking methods.

Project construction involves executing a number of activities from drawings, specifications, and details of the bill of quantities and materials properties according to the Construction Specification Institute [5] or a similar standard format. Therefore, it would be of significant importance to enhance the functionality of the materials selection process to enable choice of appropriate materials that are environmentally friendly and suitable for day-to-day operation and ease of maintenance.
2. MATERIALS SELECTION PROCEDURE

The materials selection procedure is a multi-attribute decision making problem, and these decisions are made during the early design stages of a project. The criteria for materials selection may differ from one project to another and depend on the geographic location of the project. To implement these activities, the construction company needs specific resources, including materials, equipment, labor, technicians, engineers, and technical support. An original procedure for materials selection in mechanical design was developed and implemented in software by Ashby and Cebon [6]. The procedure involved the use of materials selection charts which displayed material property data including performance indices. Jadid and Badrah [7] established that materials selection significantly affects the sustainability of a project and can markedly reduce the impact of a project on the environment. The authors also suggested the following criteria for materials selection:

a) durability  
b) maintainability  
c) sustainability  
d) aesthetic appeal  
e) adaptability  
f) lack of toxicity  
g) cost efficiency.

These can help decision-making by making it possible to consider a larger number of material options and to compare them with regard to their efficiency and effectiveness. It is of significant importance to enhance the functionality of the materials selection process and to choose the proper materials that are environmentally friendly and suitable for day-to-day operation and ease of maintenance. With this valuable information, the decision can be optimized by integrating the various contributions, as shown in Figure 1.

Figure 1. Optimal decision-making.
3. MATERIALS SELECTION USING A WEB-BASED SYSTEM

The proposed materials-selection decision support system uses a set of weighted criteria. The major source of input data for this system is a central database developed from previous and current projects, as shown in Figure 2, Jadid and Badrah [7]. The database could be used by many large organizations that own and develop facilities, such as health ministries, educational institutions, and large infrastructure projects. A large amount of information exists about materials and systems, but if this information is not recorded, it cannot be used to formulate knowledge. This database is assumed to be centrally managed at the senior level of corporate administration (design team, project management).

![Figure 2. Flowchart of decision support system, Jadid and Badrah [7].](image)

4. APPLICATION DEVELOPMENT

A system configuration for a materials database proposed by Chun et al. [8] consisted mainly of a client, a Web server, and a database, as shown in Figure 3. The system could run on a variety of platforms and frameworks and could provide a standard means of interoperation between different applications and software.

![Figure 3. Web server and database Chun et al. [8] 2007.](image)
Burbeck [9] described two variations of a model-view controller (MVC), a passive model and an active model, in an application programmed in Smalltalk-80, as shown in Figure 4. The application uses MVC V3 to create the Internet application and Razor as a view engine. Within the MVC, the term “model” refers to the objects that represent the application data and the corresponding domain logic that integrates validation and business rules. The controller interprets inputs from the user, informing the model, the view, or both to change as appropriate and the view to handle the display of information.

**Figure 4. Model Conceptual Entity**

In an MVC controller with read, write, and view functions, the controller is responsible for controlling how a user interacts with an MVC application. The SQL server database is added to App_data. A set of classes provides a database model to represent the database. The models support a variety of data access technologies, including LINQ to Entities, LINQ to SQL, and NHibernate.

### 4.1 Development of the Conceptual Entity Model

There are three ways to work with data in the entity framework:

- database first
- model first
- code first.

If the database has already been created, the entity framework can automatically generate a data model consisting of classes and properties. In the model-first approach, the entity framework designer generates DDL (data definition language) statements to create the database, as shown in Figure 5. The detailed development of such an application is summarized in Appendix A.
This research uses the code-first method, which is a new development approach in the entity framework stack that can simplify the understanding and maintenance of the domain model Flink [10]. In the code-first approach, the mapping between the stored schema and the model is represented by the code. The entity framework can automatically create the database or delete and re-create it if the model changes. In the Application_Start method of Global.asax.cs, an entity framework method is invoked to run the database initializer code using Database.SetInitializer and to create a new instance of materialInitializer() from MaterialContext, as shown in Figure 6.

4.2 Controller for Material Class

The DbSet property for each entity set, which corresponds to a database table, is created, with an entity corresponding to a row in the table in the entity framework. A MaterialController is added to the project using the entity framework with read/write actions and views. The model class used is EvalMaterial.Models; the data context class used is MaterialContext, and Razor is used for creating the material controller, as shown in Figure 7. The controller also creates the views for the material class, including Create, Delete, Details, Edit, and Index.cshtml.
In practice, it is suggested to store the images to the file system rather than in the database. The images of each material were renamed to its MaterialID and uploaded using HttpPostedFileBaseClass, as shown in Figure 8. This serves as the base class for classes that provides access to individual files that have been uploaded by a client Microsoft Corporation [11].

```csharp
[HttpPost]
public ActionResult Create(Material material, HttpPostedFileBase file)
{
    if (ModelState.IsValid)
    {
        db.Materials.Add(material);
        db.SaveChanges();

        if (file != null && file.ContentLength > 0)
        {
            var path = Path.Combine(Server.MapPath("~/uploads"), material.MaterialID.ToString() + ".jpg");
            file.SaveAs(path);
        }
    }
}
```

Figure 8: Controller creates method with image handling.
4.3 Create View for Materials

The statement at the beginning of the Create View defines the file enctype, controller name, and the method to be used to handle the file.

```csharp
@using (Html.BeginForm("Create","Material",FormMethod.Post, new {enctype = "multipart/form-data"}))
```

An input-type file is also defined using the following statement in the Create View, and the `DbSet` property for each entity set is created.

```html
<input type="file" name="file"/>
```

A filtering functionality is added to the Material Index View by added a `searchString` parameter to the Index method and a where clause to the LINQ statement. The `PagedListNuget` package also includes a `PagedList`, which makes it easier for .Net developers to write paging code. It enables the user to take any `IEnumerable (T)` and to specify the page size and the desired page index MVC3 [12], as shown in Figure 9.

![Create View for new materials](image)

**Figure 9:** Create View for new materials

4.4 Viewing Materials for Evaluation

The scaffold template is used to create list, detail, edit, and delete views based on the master layout. Each material can have several evaluations. The Evaluation view is created using the Razor view engine, and the Strongly-Typed view is selected for the `Evaluation Model` class, as shown in Figure 10. Figure 11 shows the creation of the Evaluation view using the Razor view engine.
The Evaluation list submitted for a particular supplier is shown in Figure 12.

Figure 10: Materials ListView.

Figure 11: Creation of Evaluation View

Figure 12: Material evaluation for a particular supplier
5. MATERIALS SELECTION AND WEB-BASED EVALUATION RESULTS

Miles [13] has proposed a qualitative value engineering method to evaluate alternatives for the manufacturing industries. The method includes comparing several options against weighted criteria and multiplying the satisfaction factor of each criterion or option by a criterion weight and summing the results to obtain a total score for each option. The option with the highest score is the optimum.

The detailed study involved materials selection for the construction industry for projects under design or construction and used an automated Web-based approach to help all participants in different site locations make the most feasible selection. In this work, it has been demonstrated that a participant or user can be supported in finding feasible materials required by a system which can assist the user within a Web-based environment. In addition, this work represents an effort to link materials selection with a Web-based system which can potentially assist the user in improving the process for ongoing projects. By introducing this Web-based decision support system and making it adaptable to the user, this development approach has simplified the materials selection process in a professional and user-friendly way.

6. SUMMARY AND CONCLUSIONS

Much information on materials and systems is acquired during the life span of a project (design, construction, and services). This information, if not recorded, cannot be used to formulate knowledge. Acquiring and recording information (in a database) on material and system quality, durability, specifications, and maintenance requirements is vital for obtaining high-quality materials.

This paper has demonstrated the potential of developing a Web-based materials selection decision support system for use in construction engineering. It has proposed a structure for a materials selection decision support system that can be used by consultants (designers and supervisors). The system includes a database which is used as a source of information for the decision support component. One of the most important decisions made during construction is the selection of materials to be used. A number of materials selection criteria have been identified from previous knowledge, such as durability, maintainability, sustainability, aesthetics, adaptability, lack of toxicity, and cost efficiency. These have helped decision-making by making it possible to consider and compare a larger number of material options with regard to their efficiency and effectiveness. The proposed Web-based materials selection database offers many advantages over traditional databases because it encourages greater standardization in the materials selection process for construction engineering.
APPENDIX A

A.1. The Model Classes

The model classes created in the model folder include Material, Discipline, Evaluation, Supplier, and Manufacturer. There is a one-to-many relationship between Discipline, Supplier, and Manufacturer with Material entities, and there is a one-to-many relationship between Material and Evaluation entities. As shown in Figure A.1, the Evaluations property in the Material class is a navigation property with type ICollection. This property holds all the Evaluation entities that are related to that Material entity. The SupplierID, ManufacturerID, and DisciplineID are foreign keys, and the Material entity is associated with one each of Supplier, Manufacturer, and Discipline entities.

![Figure A.1: Material class with ICollection evaluation property.](image)

A.2. Database Context Class

The database context class coordinates the entity framework with the data model in the database which is derived from the system. The Data.Entity.DbContext class is shown in Figure A.2.

![Figure A.2: System.Data.Entity.DbContext class.](image)
7. REFERENCES


