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Full Length Research Paper

Innovation in bills of quantities for engineering practice by using a hierarchical structural database with multilanguage data

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Digital documents are stored and used in many formats, especially in the case of engineering tender documents. Consequently, organization and automation are needed in order to improve access to information for all participants, and are essential for the upper management team. This paper describes an innovative approach to organizing information in a hierarchical structural database containing data in multiple languages for bills of quantities (BoQs). BoQs are used for cost estimating and form part of the engineering tender documents for contractors; they are also used during the construction stages. A methodology developed by the author contains standard translatable information, stored in a hierarchical order, so that the information can be exchanged between users with different languages. Engineering tender documents are important for contractors; in particular, for estimating overall project costs. The preparation of engineering tender documents is the responsibility of a design consultant, which implies the need for a precise, quick, and efficient method to prepare BoQs, and this method should take all components of the project into account. The format developed by the author is an attempt to standardize information in construction practice in order to establish a common basis for all engineering disciplines around the world to communicate in an effective manner, independent of language, and allowed the construction industry benefited from advances in technology.

Key words: Bill of quantities, building, construction specifications Institute, contractor, database, hierarchy, materials, multilanguage, structural.

INTRODUCTION

Engineering tender and contract documents consist mainly of the following components:

(i) **Agreement:** This describes the work to be performed, which has been agreed between the parties involved.
(ii) **Conditions of contract, including general and specific conditions:** This contains both contract provisions that are applicable to most construction contracts, written by the client, and special conditions and any additional contract provisions applicable to the specific project under consideration.
(iii) **Drawings:** These include architectural, civil engineering, structural, mechanical, electrical, telecommunications, and detail drawings.
(iv) **Technical specifications:** These provide the detailed requirements for the equipment, materials, and workmanship to be incorporated into the project. They are an explicit set of requirements to be satisfied by the materials, product, or service.
(v) **Bill of quantities:** This fully describes and accurately represents the work to be executed. Usually, BoQs list physical components and subcomponents in a structural database, with the top level representing the finished product or subassembly. A computer-based automated

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process to interface with available databases is required; this needs innovation from designers and input from other sources such as engineering based libraries.

(vi) **Survey site and soil report:** These are a general survey of the site for the project and a preliminary soil report, including studies of a number of boreholes.

This paper concentrates on the bill of quantities. This is a document that provides details of the qualitative and quantitative aspects of every constituent part of a proposed construction project, as mentioned by Hackett and Robinson (2003) and stressed by Chan (2003). It is usually a bidding document prepared by a quantity surveyor that provides an itemized list of materials and parts required to construct, maintain, or repair a specific structure, and their costs. The preparation of BoQs has developed over the years from a being a tedious manual, time-consuming procedure to a semiautomated process involving the use of computers and specialized software. The objective of this paper is to describe an effort to develop a hierarchical structural database with higher level of automation, concentrating on the case where users have more than one language.

THE CONSTRUCTION SPECIFICATIONS INSTITUTE (CSI): AN OVERVIEW

The mission of the CSI is to "advance the process of creating and sustaining the built environment" (CSI, 2013). The CSI is dedicated to creating standards and formats to improve construction documents and speed project delivery. The historical development of the CSI is well documented in the literature (Molseed, 1998). In 1998, the CSI introduced its first commercially available electronic database, and by November 2004 the CSI's classification scheme MasterFormat had expanded from 16 to 50 divisions. In 2005, the CSI Foundation was set up by the Board of Directors of the CSI for the purpose of research and educational activities in the field of construction. The CSI has organized construction information into a master list of divisions, section numbers, and titles within each division to help keep track of information about the construction requirements and associated activities of a facility. Within each division, materials are categorized into many subdivisions. Architects, builders, and material manufacturers generally follow the CSI guidelines for cataloging materials. The building life cycle addressed by the CSI is shown in Figure 1 (CSI Fresno Chapter, 2013).

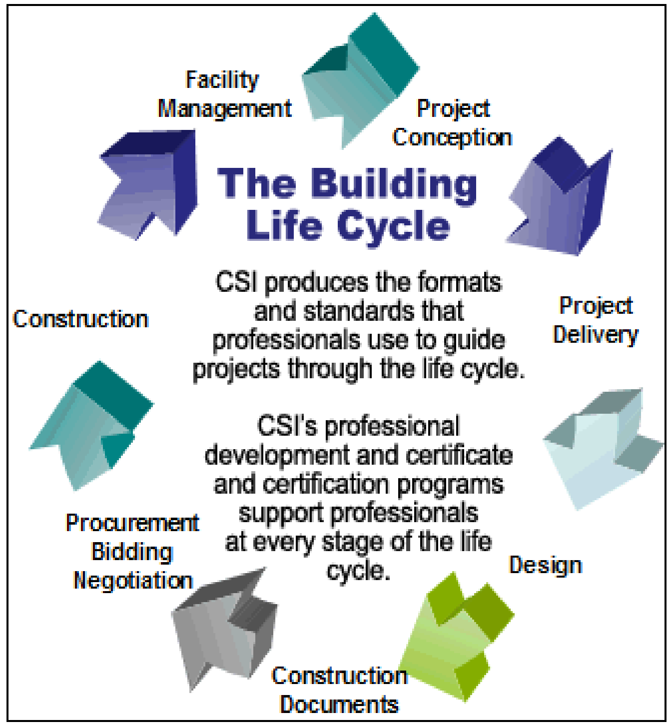

Figure 1. The building life cycle.

HIERARCHICAL DATABASE FOR CONSTRUCTION MATERIALS

A hierarchical database for construction materials is a database management system that gives users a functionality to create new databases for construction materials and can be accessed and shared with record level security. The first hierarchical database management system, known as an information management system, was created by IBM and North American Aviation to handle the vast amount of data needed for the Apollo Moon landing project, as reported by Ricardo (2012). In a hierarchical database, users insert hierarchical records and set privileges for the nodes of the database. A bill of-material system is a network of products, and develops relationships. The network can be interpreted as a directed graph without cycles (Hegge and Wortmann, 1991). An integrated document management system developed by Trinchieri et al. (2003) was used to develop a Web based application on an intranet called "Bill of Materials Profiler". This application showed how individual project teams could use a predefined interview process for collecting data regarding a targeted application or process. The materials used in a construction project include, but are not limited to, architectural, structural, mechanical, electrical, and interior components. The relationship between a construction project and the materials used represents a hierarchy. A typical approach to representing a hierarchy is to use parent and child relationships in tables; however, retrieving data and writing queries is difficult when many tables are required and are joined to each other. It is not that the physical tables cannot handle the data; rather, it is difficult to create appropriate referential integrity constraints between the tables. Such relationships also lead to complex queries, as indicated by Tegels (2008).

CONSTRUCTION MANAGEMENT INFORMATION SYSTEMS

One of the impacts of information technology on the construction industry is the increasing use of construction management information systems. However, this requires multidisciplinary skills and knowledge to meet the complex requirements of this growing industry. Caldas and Soibelman (2003) proposed a method for the automation of hierarchical document classification in construction management information systems, and have embedded classification frameworks in inter-organizational information systems such as project websites, project management software, and document management systems.

AUTOMATION OF BOQ PREPARATION

The BoQs for cost estimation developed by the author contain standard translatable information, stored in a hierarchical order, so that the information can be exchanged between users with different languages. The BoQs are written in a database format to simplify the calculation process and represent the results of mapping the engineering drawings and specifications, as described by Kirchhoff (2005). When the CSI generates a new division and uploads it to the CSI Internet server, the new division is translated into several different languages by mapping the division code, used as the primary key, and the translations are uploaded to the server. The resulting files are related to a group of languages, as shown in Figure 2.

MULTILANGUAGE HIERARCHICAL APPROACH TO THE CSI DIVISIONS

The user makes a request for information about a particular division to be downloaded in the required language, receives the file, and loads it into a BoQ or cost estimation application. The material database is organized in such a way that only the relevant information is available with full access rights to each specific engineering group of a department; however, other groups might have limited privileges to allow them to navigate the contents. Figure 3 shows CSI information organized in a hierarchical multilanguage database, and Figure 4 shows a sample of an Arabic and an English BoQ.

Table 1 lists the privilege control mechanisms. The privileges that can be assigned for the various CSI divisions are “R” for “read only,” “M” for “modify,” and “D” for “delete.” These can be used in different combinations for each CSI division or group.

APPLICATION DEVELOPMENT PROCESS

It is extremely important to protect the database and the user-level access rights model. In the system described in this paper, this is done with the MS-Jet open database connectivity (ODBC) driver (Microsoft, 2013). The Microsoft ActiveX® Data Objects Extensions for Data Definition Language and Security (ADOX) and the MS-Jet engine (Microsoft, 2013) are used for controlling and managing the data. ADOX contains objects for data definition such as tables, views, and indexes, which are useful for creating and modifying users and groups; it is used here to create hierarchical information. The security object is also used to maintain users and groups and to grant and revoke permissions for database and table objects. However, MS-Jet does not prevent anyone from opening the original database with a different, new workgroup file. Therefore, for instance, if secure access is required, it is necessary to revoke all access privileges from the “admin” user and the “admins” and “users” groups, as stated by Molseed (1998). Encrypting the database is a final option that the user might wish to adopt to secure the data. The CSI workspace is shown in Figures 5 and 6 show how to create users and groups in the workspace.

THE DESIGN PROCESS

The object-oriented design used in this paper assist in transforming the analysis model into a design model that served as a blueprint in the application development. The objects were factorized into classes; the class interfaces were defined and inheritance hierarchies were identified with the relationships among them. Class and object design is further mapped using the description of attributes and class methods. The unified modeling language has been used for the object design system where the design represents the software architecture. The modular architecture has been implemented to divide the system into subsystems or modules. Figure 7 shows the process flow module for generating a new database in the workspace. The membership settings for the groups and the settings for the users are shown in Figure 8.

Figure 9 shows the settings for the user and group permissions privileges for the CSI databases created.

Figure 10 shows the item “add” for the creation of a new CSI database. Figure 11 shows an overall hierarchical view of the components. The management of the users and groups, and their privilege settings are shown.

The view of database for multilanguage CSI elements for the database is shown in Figure 12. Each division is

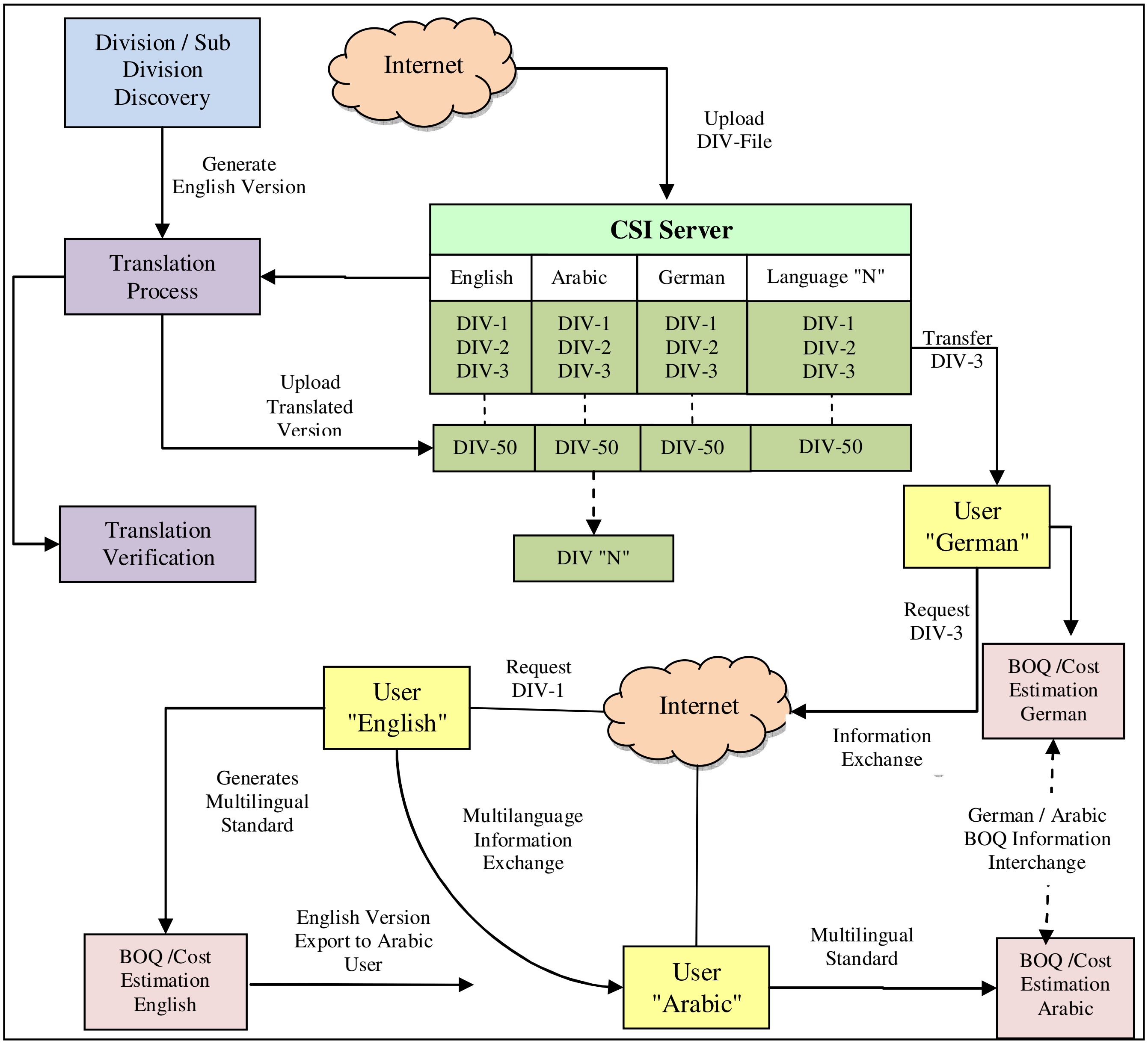

Figure 2. Exchanging of multilanguage information in a hierarchical database.

linked with appropriate sub divisions and the data is divided into two columns that are used for mapping and storing the translated data of the elements. This technique guarantees the authentic translation when switching from one language to another and generating bill of quantities in multilanguage.

CONCLUSION

It is important to have a structural database in an accurate hierarchical format to automate the preparation of BoQs in such an environment, especially in the context of a multilanguage engineering construction practice, which this paper addresses. A methodology to automate the preparation of bills of quantities using a hierarchical structural database in multiple languages in a professional and innovative way has been presented. The paper demonstrates the value of standardization in presenting information when the aim is to establish a common platform to allow engineers from any part of the world to communicate with each other, independent of their language. The hierarchical organization of information with multilanguage support reduces the time spent in generating bills of quantities in multiple languages. The method presented here should be of

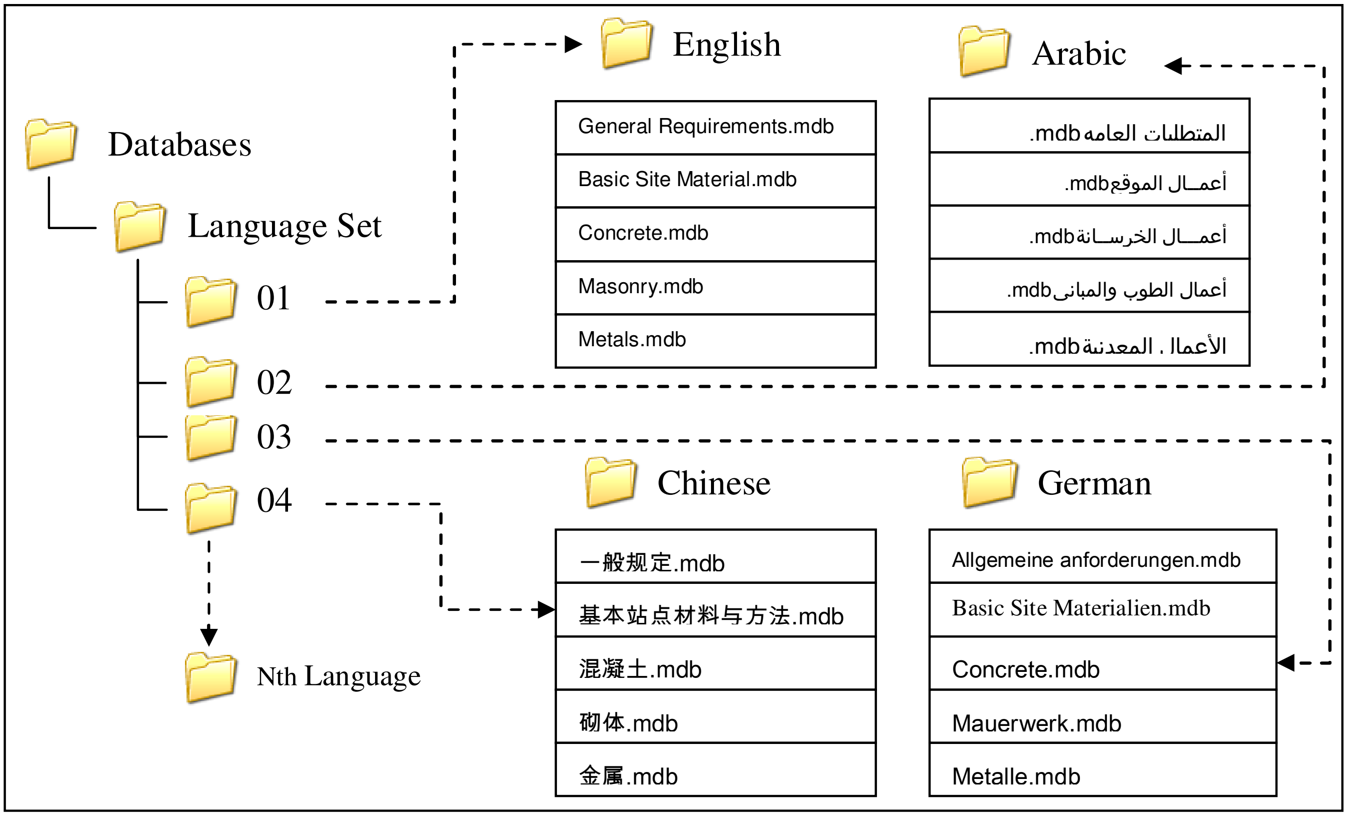

Figure 3. Accessing information from a hierarchical multilanguage database based on CSI divisions.

BILL OF QUANTITIES — جداول الكميات

BILL NO 1 — جدول رقم (1)

Institution Name — أسم المؤسسة
Country Name — الدولة
Project name — أسم المشروع

Item	Description	الإجمالي كتابة Total in words (SR)	الإجمالي رقمًا Total in figures	السعر Rate	الوحدة Unit	الكمية Qty	الـوصـف	البند
	Division 3 - Concrete						القسم الثالث : أعمال الخرسانة	
03300	CAST IN PLACE CONCRETE						خرسانة صب الموقع	03300
03300-1	Insitu plain concrete, 20 Mpa, type I cement						خرسانة عادية صب في الموقع قوة 20 ميجا باسكال واسمنت نوع I	03300-1
03300-1-1	100mm blinding concrete, 20 MPa using Type V cement				م3	450	100مم خرسانة عادية قوة 20 ميجا باسكال اسمنت نوع v	03300-1-1
03300-2	Reinforced concrete 35 MPa including formwork, reinforcement, curing, construction and expansion joint, filler boards, water stops and two-coats bituminous paint cold applied for concrete surfaces in contact with earth etc. complete as per drawings and specification						خرسانة مسلحة قوة 35 ميجا باسكال شاملة القوالب والشدات، وحديد التسليح، والمعالجة، وعمل الفواصل الإنشائية وفواصل التمدد، والواح السيلوتيكس، وجيوانات توقيف المياه،دهان وجهين من البيتومين البارد على أسطح الخرسانة المتصلة بالتربة وذلك حسب المواصفات والمخططات	03300-2
	TYPE V CEMENT						أسمنت نوع V	
03300-2-1	Footings columns and walls				م3	2150	القواعد والاعمدة والجدران	03300-2-1
03300-2-2	Grade beams				م3	190	الميد	03300-2-2

Figure 4. Sample of an Arabic and an English BoQ.

Table 1. Privileges of users and groups for the CSI divisions.

Division	Specialties	Administrator	Architecture	Civil	Mechanical	Electrical
01	General Req.	Full	R	R	R	R
02	Site work	Full	R	R/M/D	R	R
03	Concrete	Full	R	R/M/D	R	R
04	Masonry	Full	R	R/M/D	R	R
05	Metals	Full	R	R/M/D	R	R
06	Carpentry	Full	R/M/D	R	R	R
07	Th. & MP	Full	R/M/D	R	R/M/D	R
08	D, W & G	Full	R/M/D	R	R	R
09	Finishes	Full	R/M/D	R	R	R
10	Specialist	Full	R	R	R/M/D	R
11	Equipment	Full	R	R	R/M/D	R/M/D
12	Furnishes	Full	R/M/D	R	R	R
13	Sp Const.	Full	R	R	R	R
14	Conv. Sys.	Full	R	R	R/M/D	R/M/D
15	Mechanical	Full	R	R	R/M/D	R
16	Electrical	Full	R	R	R	R/M/D

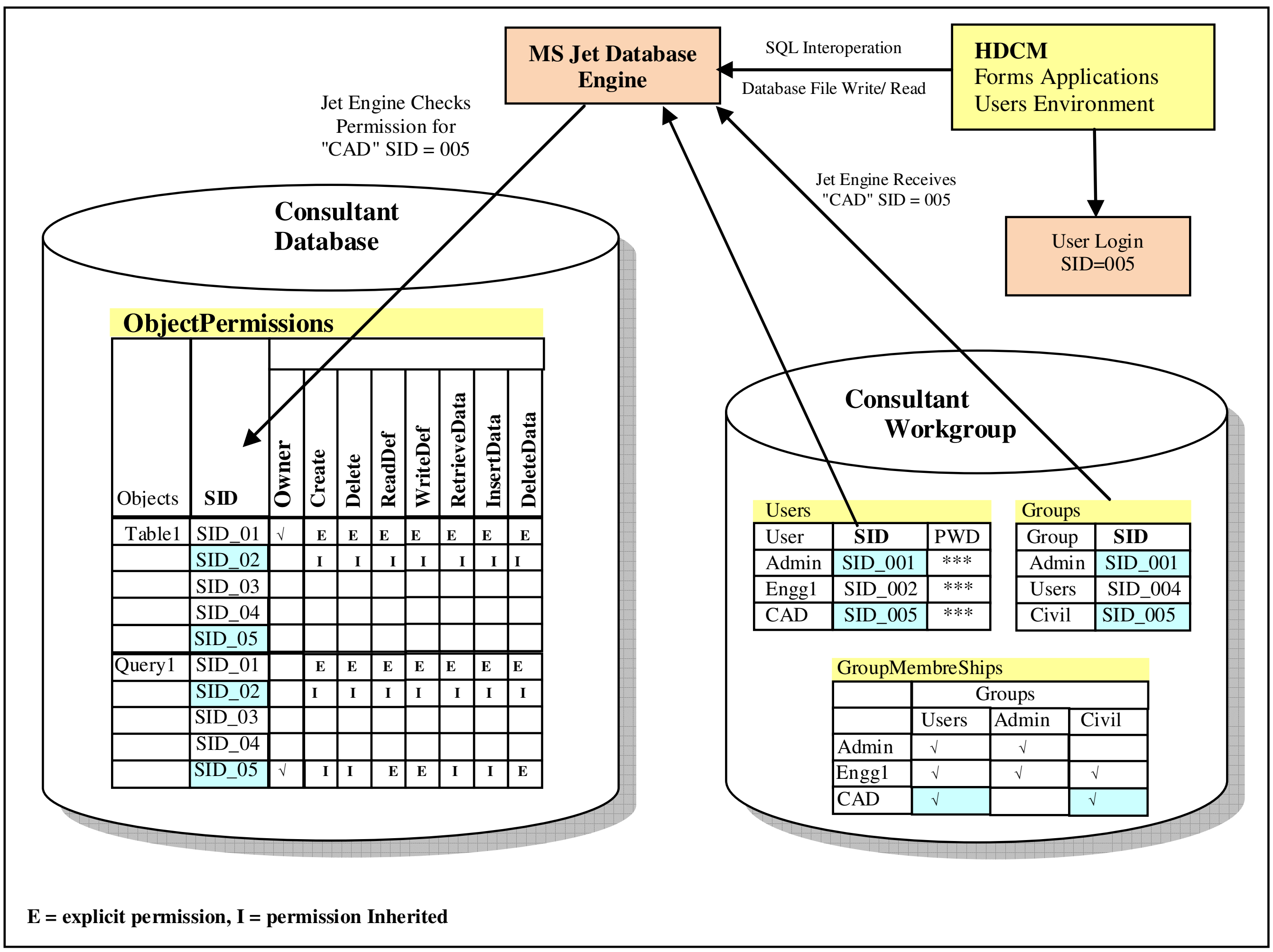

Figure 5. CSI database and workspace.

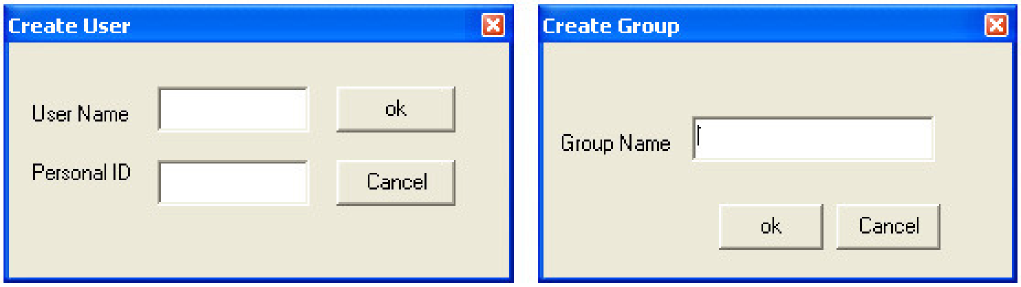

Figure 6. Creating users and groups in the workspace.

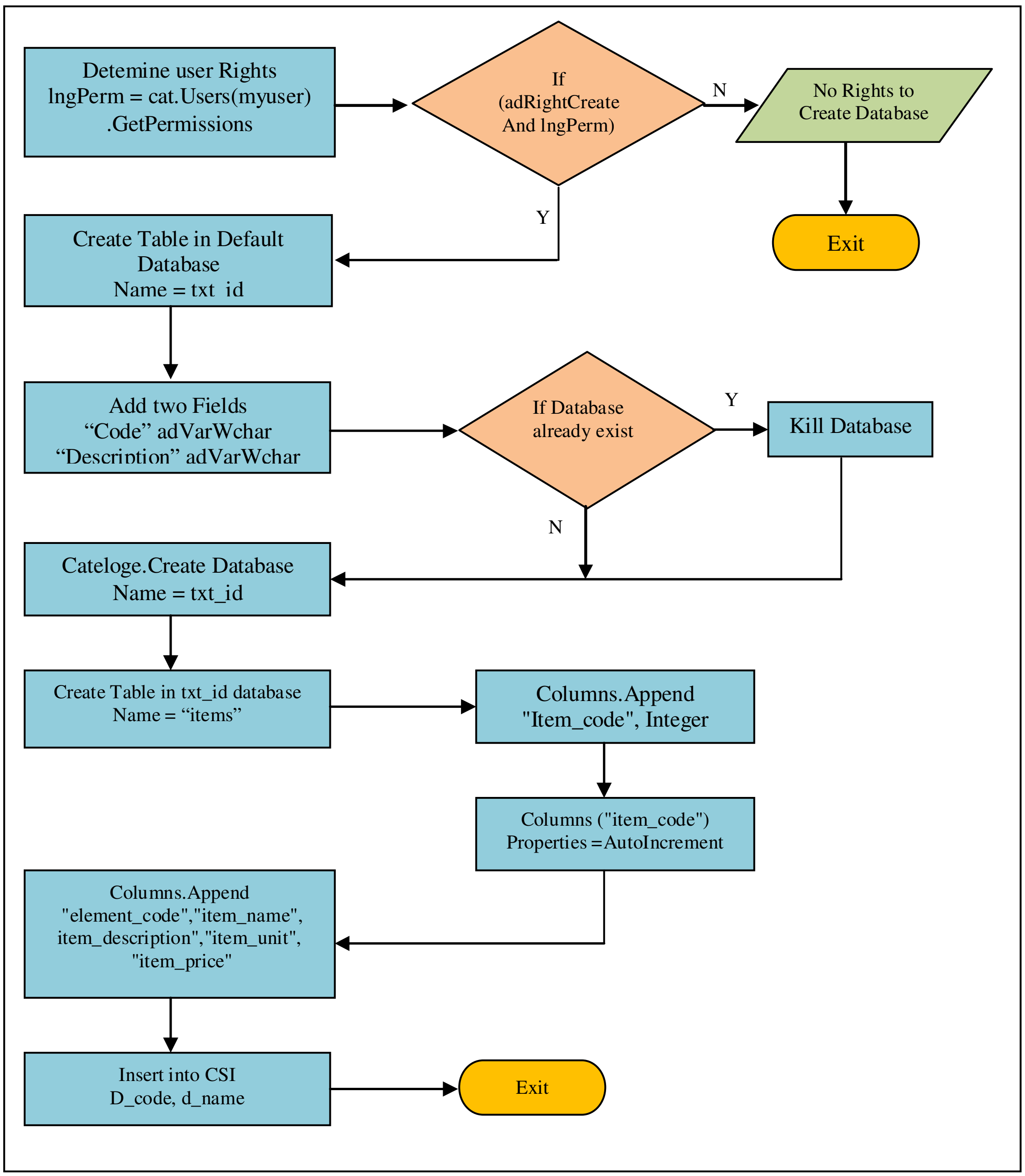

Figure 7. Flowchart process for generating database in workspace.

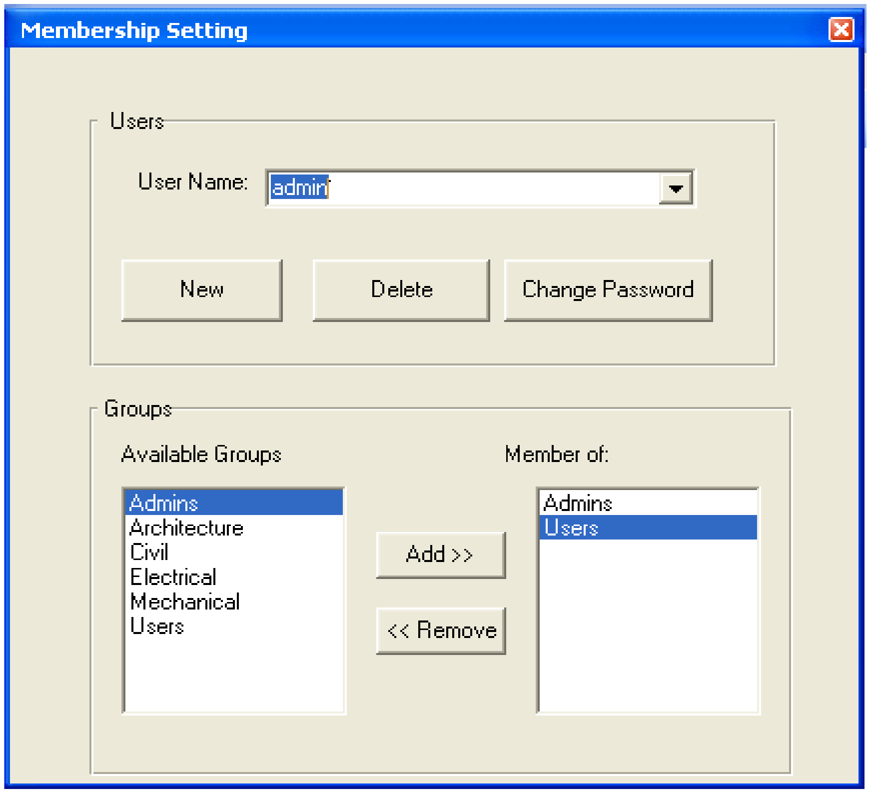

Figure 8. Group and user settings.

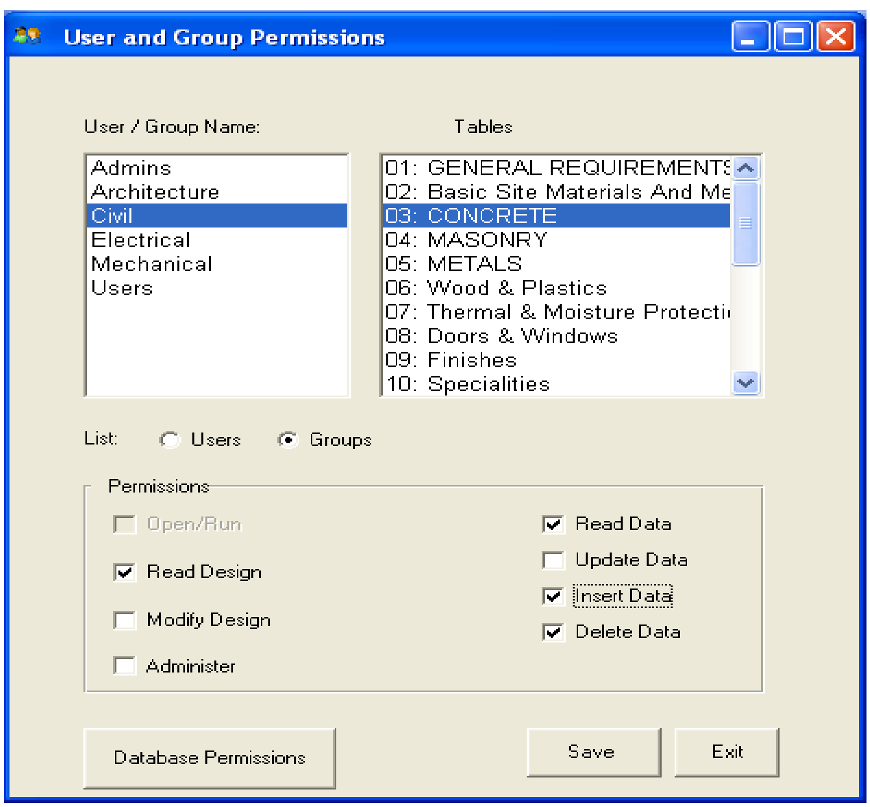

Figure 9. Privilege settings for CSI databases.

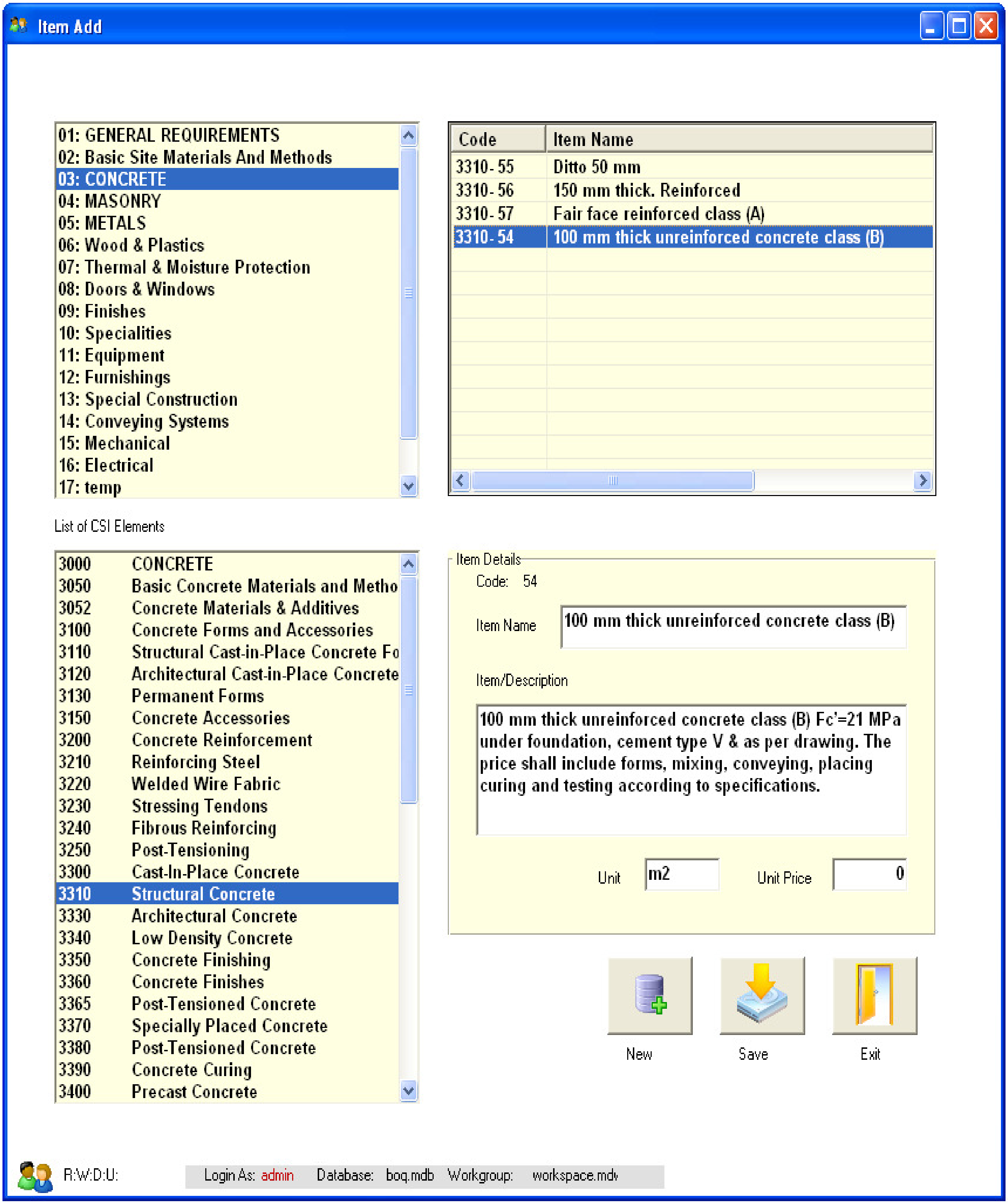

Figure 10. Creation of new CSI database.

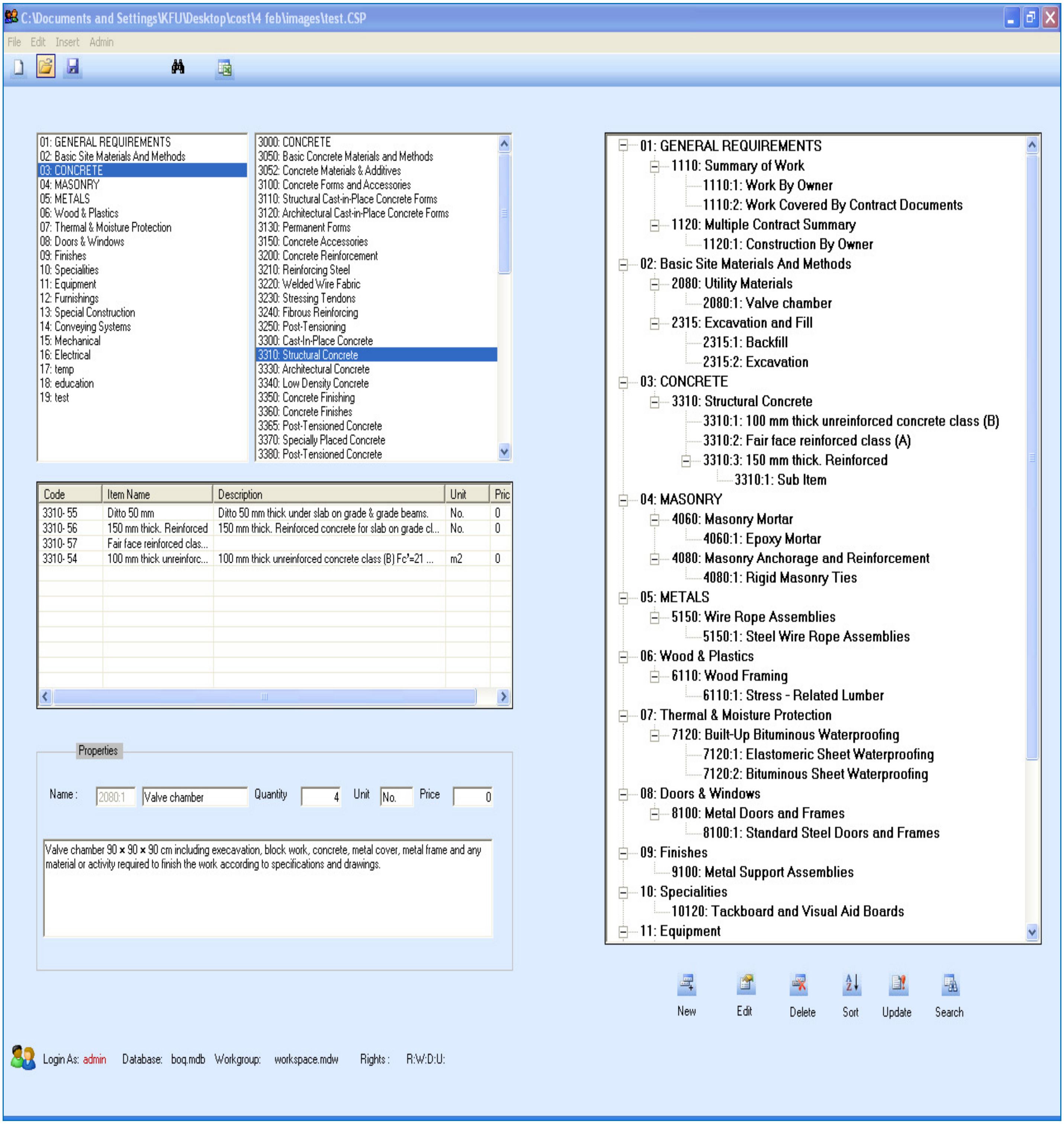

Figure 11. Overall hierarchical view of components.

special interest to the upper levels of engineering management teams, since it is essential that these people have access to information for data analysis, decision making, and various applications.

ACKNOWLEDGMENT

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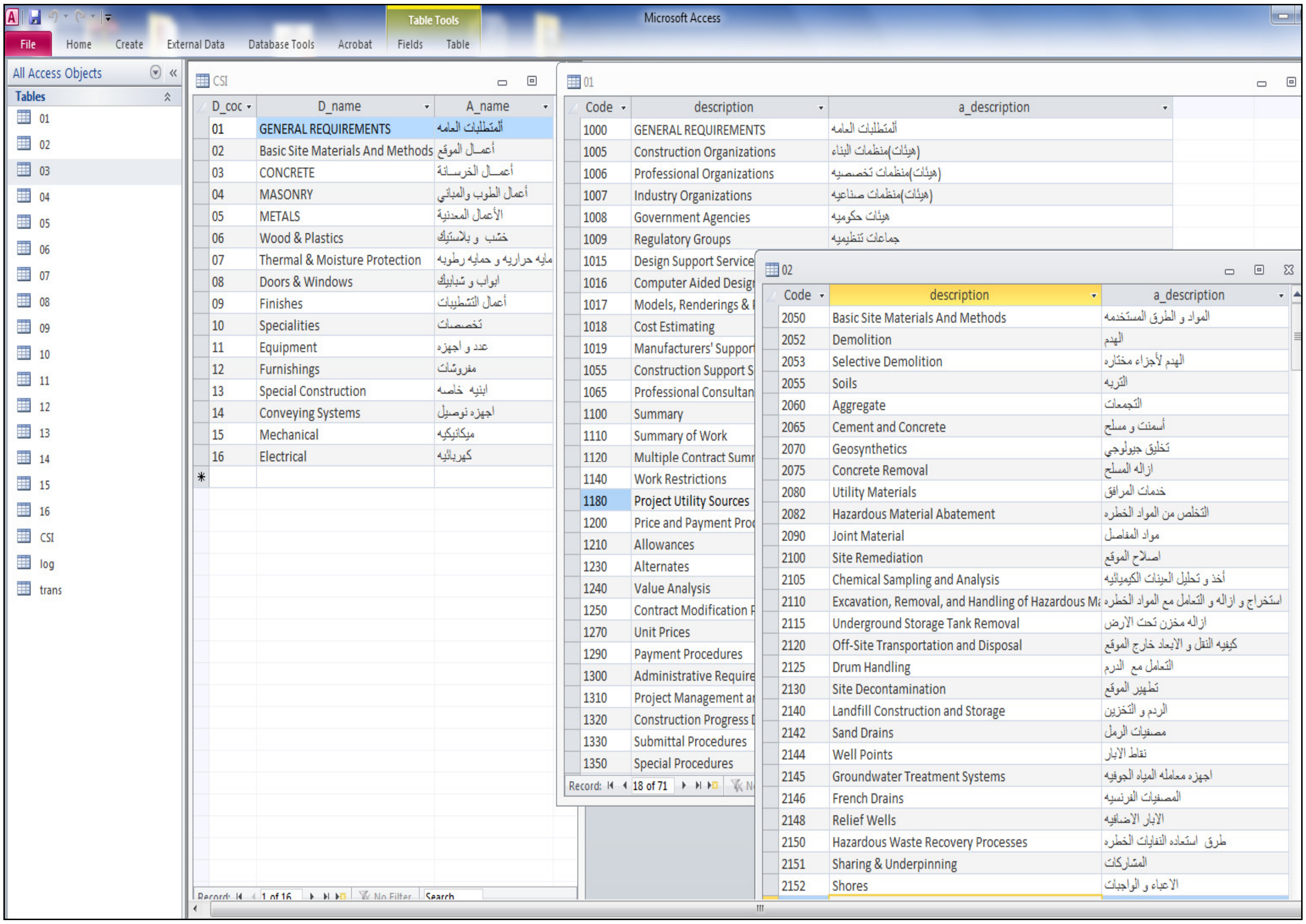

Figure 12. View of database for multilanguage CSI divisions.

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