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Simulation of a Quantity Surveying Expert System

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Abstract – Construction is the process of building or assembling of infrastructure either for residential, industrial, commercial or heavy civic activities. It is a major factor in the development of different socio-economic sectors. For the successful execution of a project, effective planning in terms of the project lifespan, the environmental impact of the project, the safety level at the construction site, availability of building materials and most importantly the cost of executing the project are all essential. Cost estimation is a well-formulated prediction of the probable construction cost of a specific building project. A number of projects have been abandoned while others were completed haphazardly, due to improper cost estimations which sometimes lead to the collapse of some buildings. This research investigates and assesses how a simulated expert system can ensure a faster, more efficient prediction of the probable construction cost of a specific building project taking into account the following parameters: current market prices of building materials, labour cost and dimensions of the proposed building. In addition, the waterfall software development methodology was adopted in building the software. Results obtained showed that proper cost estimation of projects can be achieved with minimal tendency for errors.

Index Terms: Construction, Cost estimation, Expert Systems, Quantity Surveying

1 INTRODUCTION

Estimating technologies used by contractors vary tremendously. Some make use of simple tools such as paper and pencil or spreadsheet templates while others are more technologically advanced and use computers for activities such as quantity take off, calculations, and estimating report generation. Digitizing tablets can be used to transfer the dimensions of building elements from paper onto computer.

Various stakeholders are aware of the importance of accurate project cost, right from the conceptual stage and throughout the project life cycle. The awareness of working with accurate cost has thus created a trend among various clients including private, corporate, as well as public (government), that being prudent in resource allocation is a great necessity for the successful execution of projects. Thus, in a bid to appreciate what the project cost should be, clients resort to request for cost implications of various aspects of the project for planning purposes. This cost implication is also required to have a better appreciation of the magnitude of the project, environmental cost as well as impact of the project's financial implication on the decision of the client and other stakeholders. This development led to the advent of forecasting project cost, so as to generate information which reveals what the value of a project would be in future. However, in providing project cost information, cost estimators often resort to traditional methods. Recent developments on the other hand have proven that these traditional methods, tend not to capture the details of a project's cost components, as well as intervening variables that impact the cost magnitude. Without gainsaying, once the process is faulty, an incomplete account of the project's cost and cost overrun could be the end result [1].

Early stage cost estimation will aid the project managers in their decision-making process. It allows the managers and individuals to choose adequate alternatives and to avoid misjudgment of solutions. The cost of a construction project is impacted significantly by the decisions taken at the design phase. At this stage, designers use several cost estimation methods and intuitive judgments, through their experience and data from other projects. Several methods and techniques exist for cost estimation at different phases of a project. A few of which are; traditional detailed breakdown cost estimation; simplified breakdown cost estimation; cost estimation by activity, index estimate and experts systems [2].

An Expert System (ES) is a computer system that emulates the decision-making ability of a human expert [3].They are interactive computer programs that apply a variety of knowledge elements (such as facts, rules and models) in a manner that supports and enhances problem-solving in specific domains [4]. ESs are designed to solve complex problems by reasoning like an expert, and not by following the procedure of a developer, as is the case in conventional programming. These systems are also referred to as knowledge-based systems or decision support systems.

ESs were introduced by researchers in the Stanford Heuristic Programming Project, which saw the emergence of intelligent systems like Dendral and Mycin [5]. Notable contributors to the technology were Bruce Buchanan, Edward Shortliffe, Randall Davis, William VanMelle, Carli Scott and others at Stanford [6]. ESs were among the first truly successful forms of AI (Artificial intelligence). The method of preparing an estimate using numerous paperwork containing building elements, is a difficult and time consuming process for estimators. A number of uncompleted and abandoned projects are attributable to conflict between clients (project owners) and estimators, as regards cost over-run (the difference in the actual amount being spent in project execution, and the cost estimate that was prepared initially). These abandoned or uncompleted buildings pose a combination of risks which include their use for criminal activities. Hence, the motivation for this research with the goal of reducing to the barest minimum, the number of these failed projects, by ensuring cost is estimated as accurately as possible so that buildings can be constructed to completion.

2 Review of Closely Related Works

This section takes a look at some of the closely related works in a bid to establish an ideal theoretical framework for the implementation of this research work vis-à-vis the building of the simulated ES.

2.1 An Expert Systems Approach to Highway Construction Scheduling

This entails a research carried out at the Illinois Department of transportation (IDOT) on "An Expert Systems approach to Highway Construction Scheduling". Construction scheduling which happens to be an important tool that aid contractors in building cost estimation, was identified as an aspect of construction that requires adequate and in-depth knowledge of construction methods, materials, equipment, and historical production rates for a wide range of individual activities. Factors like impact of weather, labour relations, sub-contractor qualifications, productivity and material availability ought to be studied and taken into consideration in arriving at the schedule.

This research further showed that contractors are usually given a month to examine the project, before they create these construction schedules in the bidding process which of course relates to the cost of the overall construction process. A primary estimator works with a group of key personnel to outline the parameters of the project and begin working on the estimate. Environmental requirements such as soils report or soil boring information, provided in the plans as well as weather conditions were also taken into careful considerations. Plan quantities were also checked with emphasis on items that were required in large quantity, examples of such are earthwork or paving.

It should be noted that checking these plan quantities did not equate to estimating. "For example, to determine the price per foot to install a pipe culvert, the estimator must have considered and priced such things as the size of pipe and its depth, survey layout of the pipe, the need for trench shields, trench bracing or trench dewatering; granular backfill and protection of adjacent utilities, among other factors" [7]. In the case stated, only the linear feet of pipe was expected to be included in the plan quantities. Regular visits to the site is often required to confirm vital physical constraints, such as stream crossings, access roads with weight or height restrictions, location of overhead utility lines or other obstructions that may affect crane or other equipment operations, traffic conditions, type and size of trees to be removed, soil, groundwater and potential flooding conditions, location of potential borrow or waste sites, equipment staging areas, and other conditions.

This project's main aim was the development of a software with a range of tools embedded which will assist design engineers at the Illinois Department of Transportation (IDOT) in America, create realistic construction schedules for all the projects they engage in. The knowledge-base was formed by inputs from contractors, design engineers, resident engineers, consultants, historical project records which outline a wide range of productivity rates for typical controlling items for roadway construction, including earthwork and paving activities. These recommendations were stored in a database used in the development of scheduling templates, for 12 types of road and bridge construction projects taken from a list of 49 controlling items.

2.2 A Visual Approach to Construction Cost Estimating

The aim of this research was to use visualization to aid estimation of construction costs. This was accomplished by developing a software application that digitally transfers project information from a Building Information Modelling (BIM) model, to the estimation application,

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thus allowing minimal manual entry. The estimator can select elements interactively through a generated virtual building. The developed Visual Estimating Application creates a 3D–CAD (3-Dimension Computer Aided Design) model, with navigation and interaction made possible with visualization modules. The resulting information extracted from a 3D CAD model, is used for the estimation and the cost data is stored in a relational database model, representing the cost estimating database [8].

The developed visualization module interfaces with a Revit Architecture using Revit API (Application Programming Interface), via C# programming language and extracts from a Revit91 model, not only a building element's geometry, but also element material properties. Autodesk Revit is a BIM software for architects, structural engineers and contractors which allows users to design a building and its components in 3D. Microsoft DirectX graphical library was implemented within the visualization module to, generate a virtual prototype of the project [8].

Figure 1: Database Management Dialog Box [8]

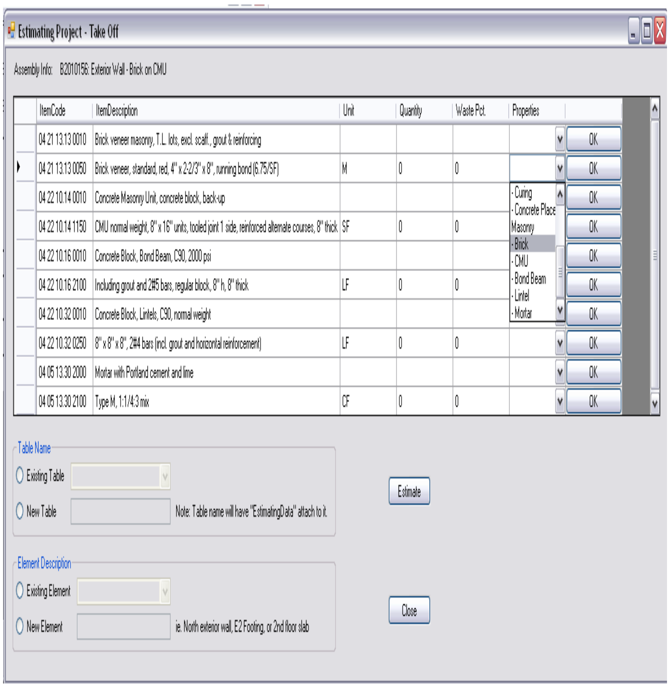


Figure 2: Different Items for the Assembly is shown in the dialog box [8]

The Visual Estimating Application as shown in Figures 1 and 2, takes an element extracted from a Revit Model, maps it to an assembly from the cost estimating database for preparing an estimate, and generates a report. The application is very useful in estimating costs but still relies on the input in terms of judgment and experience of the estimator (The Expert). The resulting application in addition to giving the user a visual interface for cost estimating, can teach students or novices who have no experience in construction cost estimating. This research has provided an avenue to commercialize cost estimating creating opportunities for future research and developments.

Despite the elaborate nature of the application, the database is limited to elements such as concrete and masonry and the research focused primarily on the on Autodesk Revit architecture even though other BIM packages exist in the market.

2.3 A Building Cost Estimation Model Based on Cost Significant Work Packages

The aim of the research was to outline the constraints from the unstructured nature of the cost estimation practice in Turkey, producing a generic computer aided building cost estimation model. The software still in testing phase is used for educational phases. Future work for the research includes the use of public and current market prices, increasing number of projects stored in the database, estimating costs of different types of projects and calculating the cost significant value factor more precisely, by using statistical techniques to improve functionality [9].

2.4 Expert System-based Predictive Cost Model for Building Works: Neural Network Approach

In this work, the designers made use of past construction projects of the two consecutive years prior to the start of their research. The model was developed and tested as a predictive cost model for building projects based on Multilayer Perceptron Artificial Neural Networks (ANNs). The model could make predictions with minimum error as highlighted by their results, which showed a maximum variation factor of 7.42 percent. This variation also takes into account corruption escalation and inflation. The model which is a step ahead of regression models, is capable of helping professionals save time, make more realistic decisions, and help avoid underestimating and overestimating of project costs [10].

3 Methodology

The software development methodology employed in the development of the simulated expert system is the waterfall model. In this model, software proceeds through an orderly sequence of transitions from one phase to the next [11]. Information was derived from relevant experts in the quantity surveying field to form the knowledge domain, through structured interviews, reports on completed projects, related books, journals as well as regular interaction with the expert to elicit knowledge in some systematic way. The knowledge thus obtained was stored in a human friendly intermediate representation and analysed to form the knowledge base of the system.

The system was designed with a module that holds details of the current economic situation incorporated in the knowledge base of the system. The cost of the building elements are calculated with respect to the percentage of inflation before the estimate is made, and thus inhibit conflict caused by lack of trust between construction owners and estimators who submit a cost estimate initially and then submit another due to inflation. In addition, the system employs a user-friendly interface through which the end-user is asked some questions and the answers given are fed into the system, to produce some calculations before a report is given. This serves as a useful tool in the hands of experts, as it works as an assistant to handle details of planning or to suggest alternatives. With an automated assistant, more detailed and accurate activity networks is made feasible and cost effective. The system was implemented using web applications employing the following languages and tools: Hypertext Preprocessor (PHP) as seen in figures 3 and 4, Hypertext Markup Language (HTML), Cascading Style Sheet (CSS), Java Script for the web development, MySQL for building the database and WAMP which acts as the server for the system, for easy access to users covering the following construction phases: excavation, foundation, laying of blocks, lintel, wall, roof and floor finishing as shown in Figure 5.

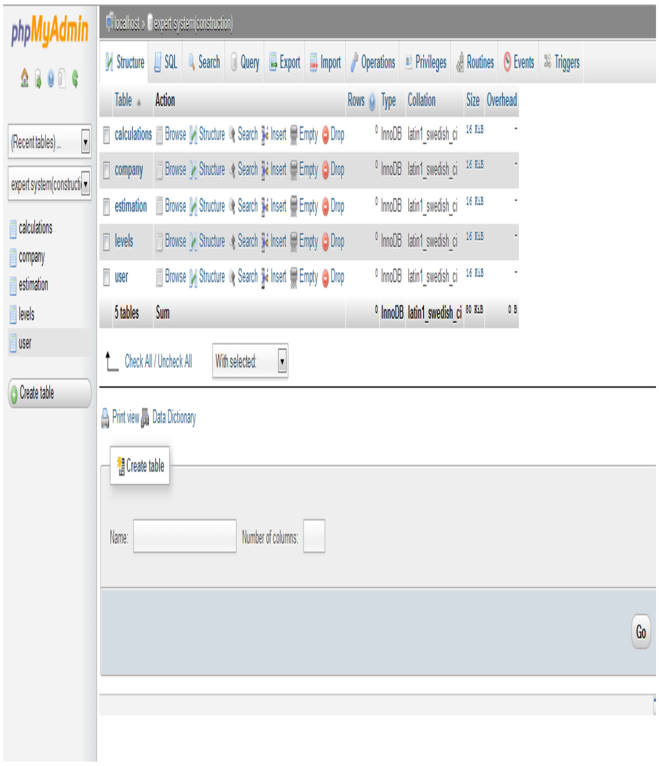


Figure 3: The Application Database

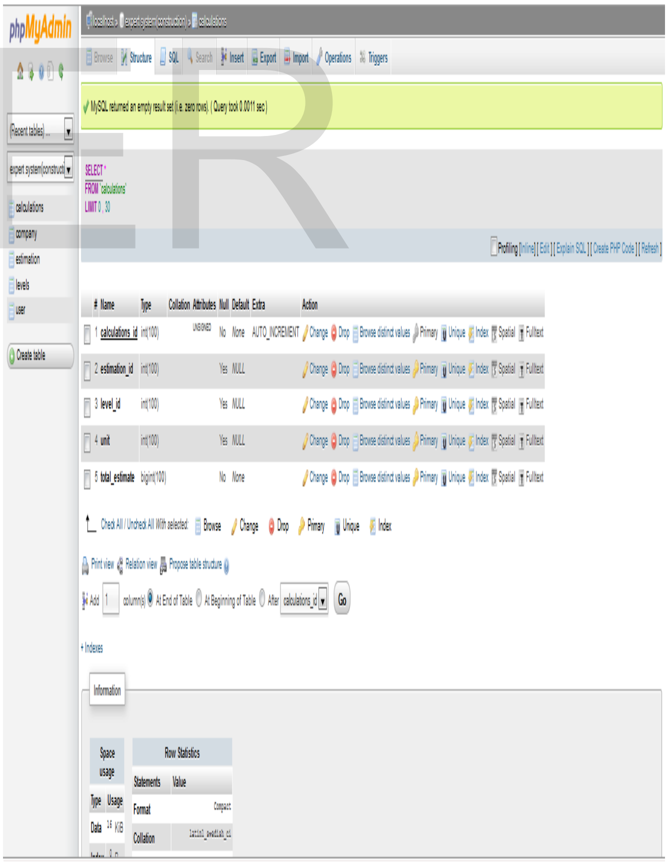
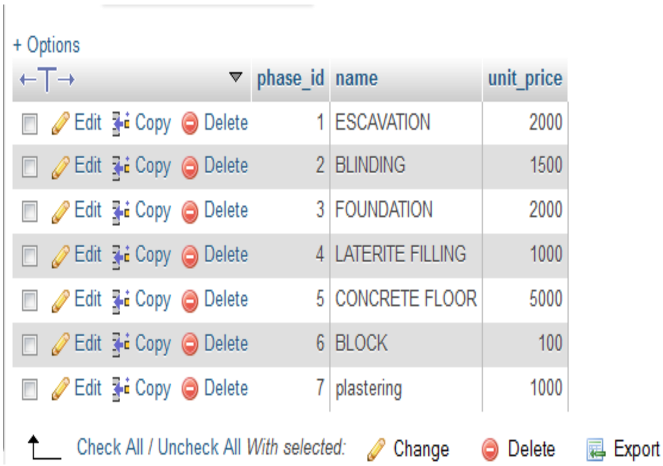


Figure 4: The calculation table



	phase_id	name	unit_price
Edit Copy Delete	1	ESCAVATION	2000
Edit Copy Delete	2	BLINDING	1500
Edit Copy Delete	3	FOUNDATION	2000
Edit Copy Delete	4	LATERITE FILLING	1000
Edit Copy Delete	5	CONCRETE FLOOR	5000
Edit Copy Delete	6	BLOCK	100
Edit Copy Delete	7	plastering	1000

Figure 5: The phase table

4 Results and Findings

The simulated expert system is user friendly and easy to use, taking into consideration various parameters like current market prices of building materials, labour cost and dimensions of the proposed building. The system comprises of the front-end and the back-end. The front-end of the system includes the interface of the system, what the users can see and includes components such as the login page (figure 23), the expert page, the homepage and the novice page. These front end components are linked to the back-end component which is the database of the system. The simulated ES consists of web forms, also known as web pages. These web pages include: Novice, Administrator and Logout. Access is denied for any login attempt without authenticated credentials (figure 24). The Novice has the ability to: create an estimate, view estimate and view breakdown of estimate as shown in figures 6, 7 and 8.

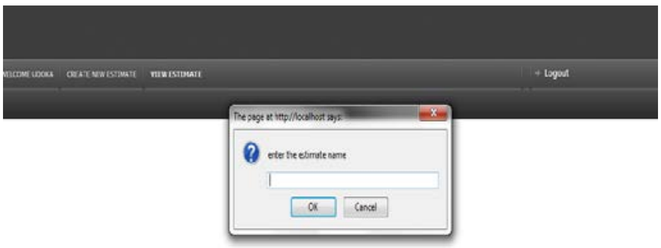


Figure 6: Create Estimate

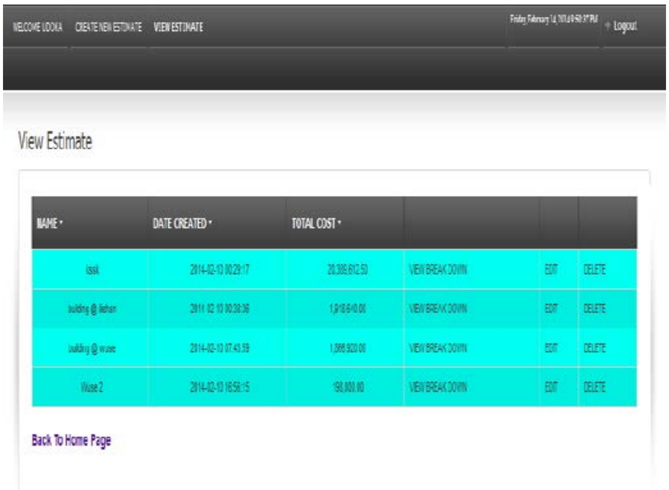


Figure 7: View Estimate

Figure 8: View Breakdown of Estimate

The Administrator has the ability to; add wall material, add floor material and change price of bricklayers as shown in figures 9, 10 and 11.

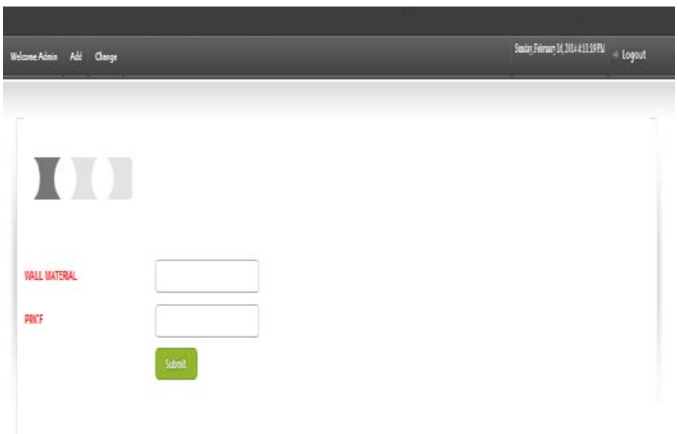


Figure 9: Add Wall Material

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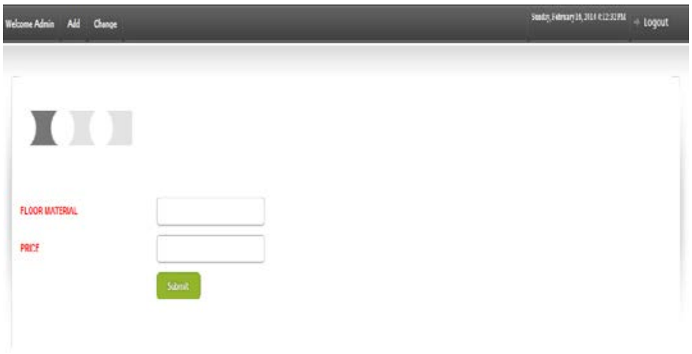


Figure 10: Add Floor Material

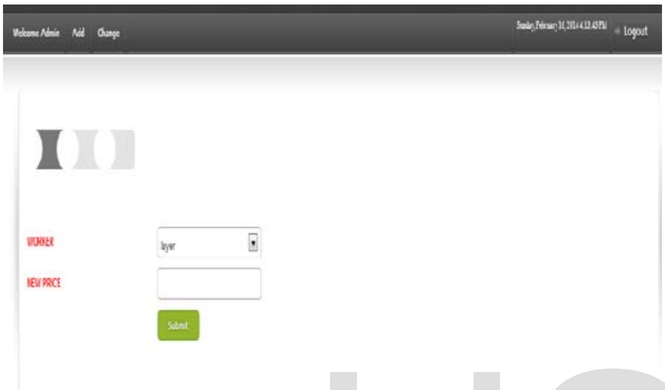
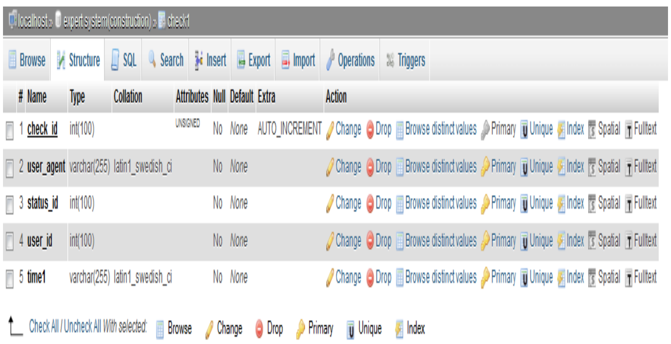


Figure 11: Set New Price of Workers

A crucial level of the system is the testing phase which involves testing all the various components of the application function to reveal all error such as computational errors, memory errors and logical errors.

The tables of a database are the main containers of the database, they hold details and allow relationships. Tests were conducted to ensure that type constraints, null and not null constraints, uniqueness checks, length checks, and numeric checks were properly implemented.

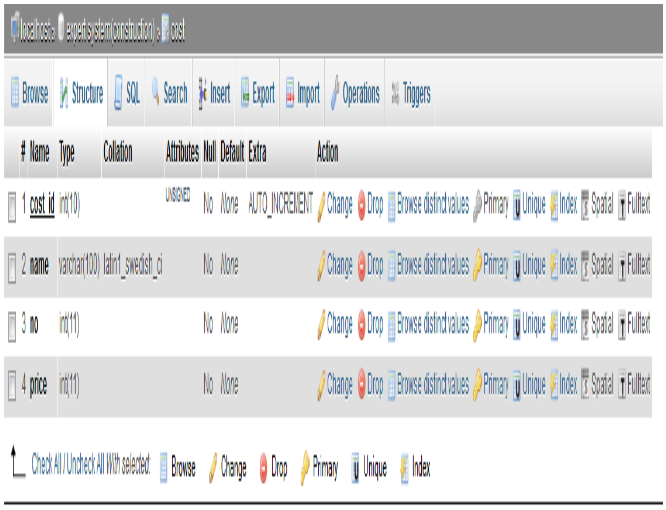


localhost » expertsystem(construction) » check

#	Name	Type	Collation	Attributes	Null	Default	Extra
1	check_id	int(100)		UNSIGNED	No	None	AUTO_INCREMENT
2	user_agent	varchar(255)	latin1_swedish_ci		No	None	
3	status_id	int(100)			No	None	
4	user_id	int(100)			No	None	
5	time1	varchar(255)	latin1_swedish_ci		No	None	

Figure 12: Check Table

The check table as shown in figure 12, holds the login record of each user, keeps a record of the last time the user logs in and the agent used.

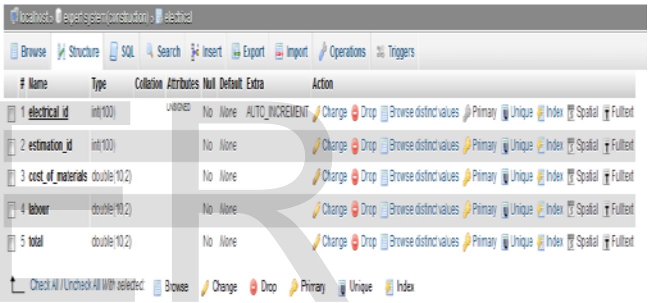


localhost » expertsystem(construction) » cost

#	Name	Type	Collation	Attributes	Null	Default	Extra
1	cost_id	int(10)		UNSIGNED	No	None	AUTO_INCREMENT
2	name	varchar(100)	latin1_swedish_ci		No	None	
3	no	int(11)			No	None	
4	price	int(11)			No	None	

Figure 13: Cost Table

The cost table shown in figure 13, contains the cost of carrying out finishings to different segments of the building while figure 14 entails the electrical implications of the project.



localhost » expertsystem(construction) » electrical

#	Name	Type	Collation	Attributes	Null	Default	Extra
1	electrical_id	int(100)		UNSIGNED	No	None	AUTO_INCREMENT
2	estimation_id	int(100)			No	None	
3	cost_of_materials	double(10,2)			No	None	
4	labour	double(10,2)			No	None	
5	total	double(10,2)			No	None	

Figure 14: Electrical table

localhost » expertsystem(construction) » estimation

#	Name	Type	Collation	Attributes	Null	Default	Extra
1	estimation_id	int(100)		UNSIGNED	No	None	AUTO_INCREMENT
2	name	varchar(255)	latin1_swedish_ci		Yes	NULL	
3	date	timestamp		on update CURRENT_TIMESTAMP	No	CURRENT_TIMESTAMP	ON UPDATE CURRENT_TIMESTAMP
4	user_id	int(100)			No	None	

Figure 15: Estimation table

Figure 15 shows the table that holds the details of the estimation being created.

Figure 16: First Table

Figure 16 entails the table holding the value of the first step being performed by the system, in carrying out the estimation of the building which include excavation, blinding and foundation.

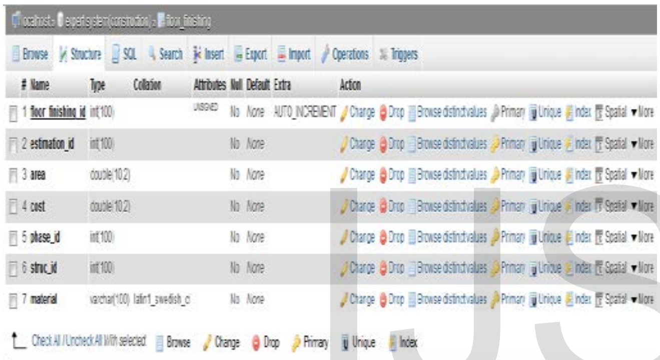


Figure 17: Floor_finishing Table

The floor finishing table holds the values calculated for the floor finishing of a segment of the building as shown in figure 17, it contains the id of the estimation we are estimating, the total area of the segment, cost and the material used.

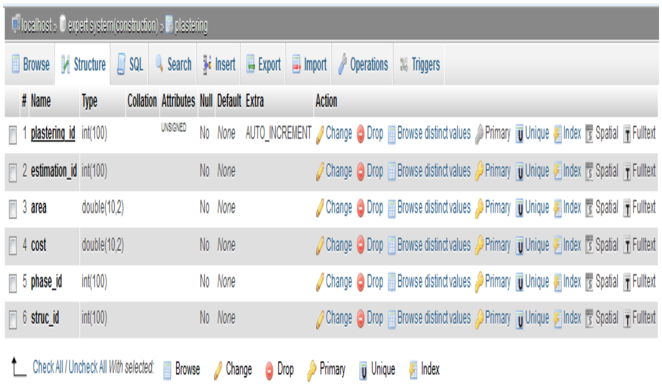


Figure 18: Plastering Table

The plastering table as shown in figure 18, holds the values calculated for plastering a segment of the building, it contains the id of the estimation being estimated, the total area of the segment cost and the materials used.

Figure 19: Plumbing Table

Figure 19 entails the plumbing table, which holds the values calculated for carrying out plumbing work in the building, it contains the id of the estimation being estimated, cost of the materials used, cost of labour and the total price.

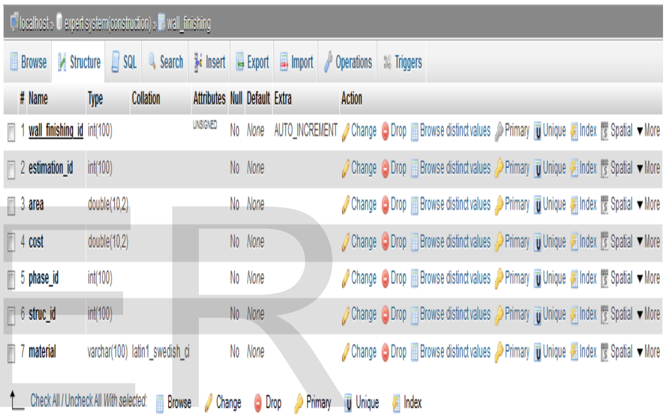


Figure 20: Wall Finishing Table

The wall finishing table holds the values calculated for wall finishing as shown in figure 20, it contains the id of the estimation being estimated, the total area of the segment, cost and the material used.

Figure 21: User Table

The user table shown in figure 21, holds the users' data: name and login details (username and password).

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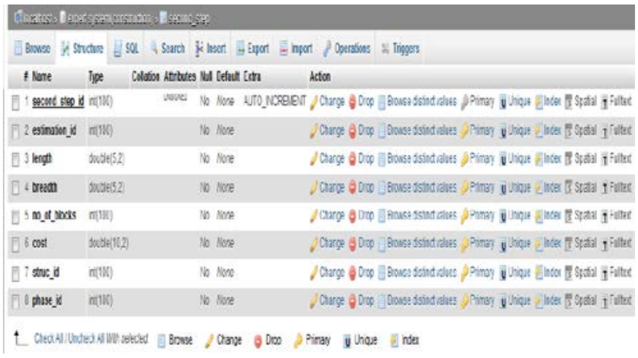

Figure 22: Second_step Table

The second step table holds the value of the second step being performed by the system which is laying of blocks as shown in figure 22.

Testing – The technique used in testing the interface of this software is the black box testing. Black box testing is also known as functional or behavioural testing and may be described as a type of testing, based on analysis of the specification of a piece of software without reference to its internal workings, generally performed by those individuals who have no real knowledge of how the software works. It is based on requirement and functionality with the goal to test how well the component conforms to a predefined test specification, given a sequence of inputs. The test mechanism seeks to catch/detect user errors or faults in the system. The modules that are data oriented were tested in this phase.

In testing the login page the test case was a set of incorrect input; incorrect username or password for the user and the next is the correct username and password. The system generates an error for an invalid input but navigates to the user's page when a correct username and password is supplied (see figures 23, 24 and 25).

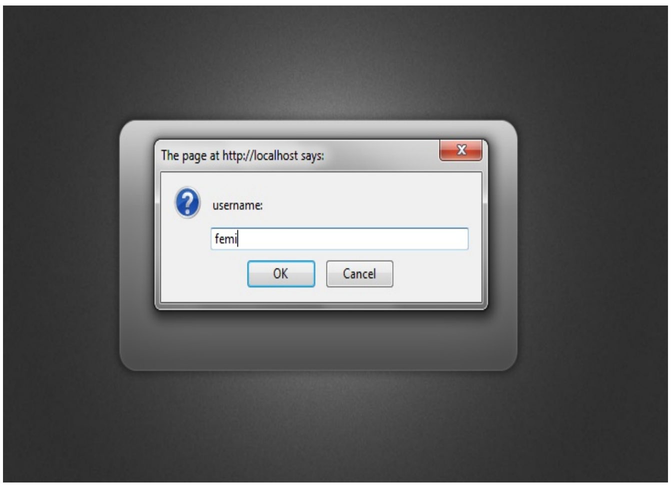

Figure 23: Login Page

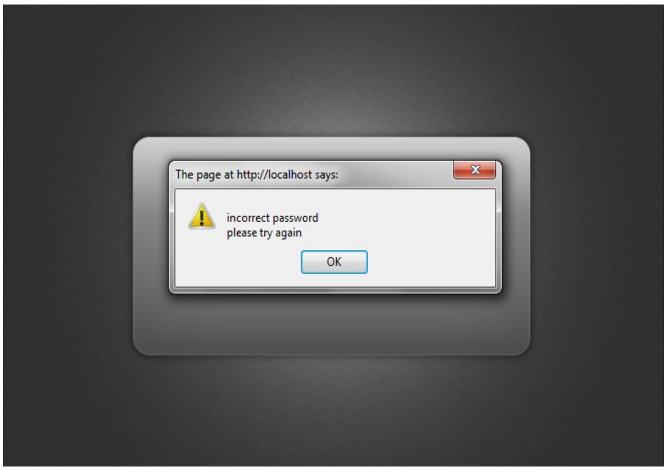

Figure 24: Invalid Login

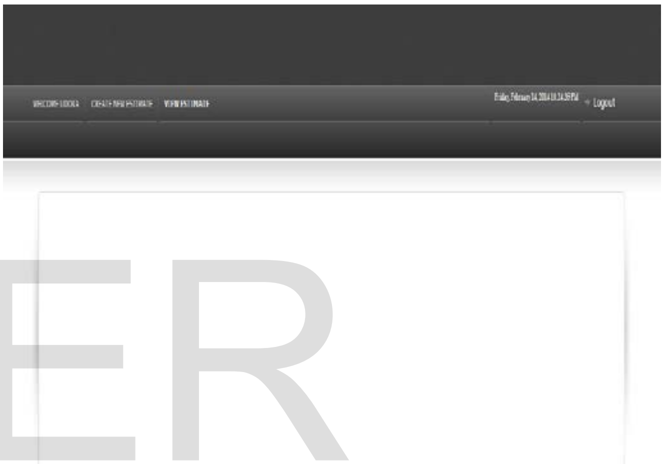

Figure 25: The user's page after a successful login

The minimum requirements of the application based on its testing, analysis and design are given as follows:

i. The system will request username and password form users to gain access to the system.
ii. The system will ensure that values are assigned to the right estimation.
iii. The system will ensure that no user can have access to the information of another user.
iv. The system will automatically calculate the cost of construction from the values being supplied by the user.

The minimum hardware requirements include:

i. Main processor: Pentium IV
ii. Random access memory: 512 MB
iii. Hard disk capacity: 5 GB

The minimum software requirements for the system to be accessible include:

i. Operating system: Windows (98, 2000, ME, NT, XP, Vista, 7), Linux, Mac OS.

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ii. A web browser, Mozilla Firefox (most suitable).
iii. Virtual server: Xamp version 1.7.1, Wamp server Version 2.2.

5 Recommendations

This research is limited to the development of an application to estimate the cost for residential buildings. The system could be further specialized to allow; upload of building plans and thus automatic generation of the required measurements for estimation, estimation of constructions such as roads or bridges, generation of a 3D image of the building that can be easily modified to suit the budget of the client.

6 Summary

The process of building or assembling infrastructure is a major factor in the development of different sectors of a place. For the successful execution of a project, effective planning in terms of the project lifespan, the environmental impact of the job, the safety of the construction site, availability of building materials and most importantly how much the project will cost, is essential. The waterfall software methodology was used because it ensured a systematic approach to the development of the software, the result of which is a simulated expert system that ensures a faster, more efficient prediction of the probable construction cost of a specific building project.

7 Conclusion

As of today, the human knowledge of a domain is either dispersed in books and journals or exists in the minds of experts. By simulating the expert systems technology, the stored knowledge is then available to users in a user-friendly manner, using natural language like English. Unlike manufacturing, construction is non-repetitive, each project being different than the other in design, layout, materials used, construction methods, time, crew strength and management. In order to do a good estimate and in lesser time, the simulated ES could be used.

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