AN EXPERT SYSTEM FOR A COMPETITIVE BID
ESTIMATION OF AN ELECTRICAL INSTALLATION
PROJECT

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Degree of Master of Science

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Sri Lanka

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree
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Sri Lanka

September 2013
Declaration

“I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Signature: 
(T.M. Weerakkody) 
Date: 

The above candidate has carried out research for the Masters Dissertation under my supervision.

Signature of the supervisor: Date
(Dr KTMU Hemapala) 

Signature of the supervisor: Date
(Dr AGBP Jayasekara)
Dedication

This is my first research work which is successfully concluded and this will dedicated to my wife Mrs. Nilanjana Senevirathne, who has been always supporting me to make my dreams come true.
Acknowledgement

My heartiest gratitude is granted to Dr. Udayanda Hemapala who inspired me to start master level studies and guide me every step in which the research would be followed successfully and on the other hand, Dr. Buddika Jayasekara who has kept me on the track where conceptual directions were necessary to move forward and without his guiding, there won’t be a research like this.

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And also acknowledge Mr. Sagara Gunawardana who was the managing director of Venora International Projects (pvt) Ltd. And his support and release my duties to attend all lectures and seminars. And my team members who came from different organizations with different kind of experience and expertise knowledge with which i had the opportunity to share.

Finally, I gratefully thank my parents who wish my success all the time. My family and friends who have shared ups and downs in my life evenly and the doctrine of load Buddha which I believe the only truth that people can survive and enlighten one day.
Abstract

Construction Industry in Sri Lanka has started to boom from few years back and is going to reach its peak now, therefore, companies require to have more attention on bid estimation in terms of the accuracy and the competitiveness since there are lots of competitors who are always searching for winning their bids.

When it comes to electrical installation field, it is more complex and must be handled by experience quantity surveyor (QS) with a sound supervision from an electrical engineer so that requirements stipulated in the bidding documents are to be well-understood and quoted accordingly.

However the current issues are (i) all the electrical contractors cannot afford to have expertise knowledge on this context and even if had, cannot employ for continuous operation because it tends to reduce the accuracy level of the output. (ii) Conventional estimation techniques are still not reviewed so that continuous improvements on techniques of bidding should be promoted so that introduction of more reliable system would be useful to reduce the complexity of bid estimation process and release the pressure on the estimator in turn. (iii) Application of software base expert systems is still not developed and not applied in the electrical installation perspective in Sri Lanka and implementing such a system should be considered to solve the matter efficiently.

Therefore this research will use expertise knowledge to build a knowledge base expert system and the same will be implemented in software base so that the end result is to overcome prevailing issues in electrical bid estimation in Sri Lanka.
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## Abbreviations

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<tr>
<td>ES</td>
<td>Expert System</td>
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<tr>
<td>FIDIC</td>
<td>Federation International des Ingenieurs counseils (International federation of consulting engineers)</td>
</tr>
<tr>
<td>JICA</td>
<td>Japan International Corporation Agency</td>
</tr>
<tr>
<td>ICE</td>
<td>Institute of Civil Engineers</td>
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<tr>
<td>NEC</td>
<td>National Electrical Code</td>
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<tr>
<td>ICTAD</td>
<td>Institute for Construction Training and Development</td>
</tr>
<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<tr>
<td>BOQ</td>
<td>Bills of Quantities</td>
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<td>QS</td>
<td>Quantity Surveyor</td>
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<td>OHP</td>
<td>Overhead and Profit</td>
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<td>USAF</td>
<td>United states Air Force</td>
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Chapter 1: Introduction

1.1. Background

Estimating of work in the electrical installation field is considerably covered with lots of technical aspects, architectural aspects and workmanship aspects. It is because of that the electrical installation is the main system that the building is made to be functional which means that all the building services are kept active throughout the building operation lifetime. In addition, electrical system of a building is always unique. Estimator or Quantity Surveyor [1] has to have sound knowledge of electrical works in terms of the, standards, regulations and installations points of views in order to get a value of money for erecting, installation and commissioning works.

In general, departments or parties which involve in estimation works particularly related to electrical installation are always put the estimators under supervision of expertise person. Because electrical system is always subjected to change in the scope from project to project unpredictably unlike structural work, wall and masonry work, plumbing services and etc. therefore general knowledge about the electrical work would be very important to get the final results towards more accurate one. Having knowledge about electrical symbols, installation methods, material and accessories as described in [2]. Less confusion about the estimation work will be ensured.

The bid estimation process in relation to the electrical installation has been covered with the basic material cost, labour cost and overhead and profit as it is worked out in the other fields. Material cost could be expressed in generally two ways as in the bills of quantities. Those are item rates and unit rates. Whichever comes under estimation process, Material take off will be taken by referring to construction drawings and specifications. Then the total quantities are summarized in order to get prices of material from the relevant suppliers as a bulk supply. Then the prices will be based on the bulk production which is discounted unlike the retail prices. Labour cost will be calculated by using market rates where it should be up to date all the time.
Generally labour rates which are used for the estimation will be decided by using cost of similar jobs which has been done by the company. Then the overhead and profit is generally called as markup will be set up by the management of the company where it belongs to managers who would make decisions based on turnover, actual overhead, future goals etc.

However, more or less proper estimation for the electrical installation has been developed from the past to the present of the construction industry with making improvements and adding different kind of concepts which led to put the both contractor and the investor with minimum risk involvements in terms of costing and operations. Now a day, it has been developed specialized areas which are the subdivisions of the total scope of electrical installation and then the contractor has now some sort of flexibility on bid estimation. Because contractor has now so much of options to come up with more reliable pricing by getting involvement of those kind of specialized field organizations, sub contractors etc. basically followings are the sub divisional areas where we can find specialized sub contractors in the same categories.

a) High Voltage Switchgear panel installation 
b) Transformer Installation 
c) Generator Installation 
d) Low voltage switchgear panel installation 
e) Cable Management system installation 
f) Lighting installation 
g) Lightning protection system installation 
h) Earthing system installation

Therefore, the electrical estimator has now advantage over producing more reliable estimation because of sub divisional field areas where specialized involvements are taken place for individual items. However bid estimation process is in general getting a value for a series of jobs which are described in set of documents in field of electrical installation.
Therefore, estimator should have sound knowledge about the tender process, relevant documents and cross references related to particular jobs in which the scope, relevant standards and specifications are described and more importantly estimating methods where QS can implement according to the type of the contract, specification and construction drawings.

Knowledge of the contract regulations is very advantageous since it is the law that both the contractor and the client are bind together. Generally there are FIDIC, JTC, ICE, NEC and locally ICTAD. Describing contents of each of them is out of scope of this thesis. But to get brief understanding, some of the important topics in ICTAD regulations are shown below.

According to the ICTAD regulations, [3] there are four (04) categories of Standard Bidding Documents for Procurement of works, those are,

1. Procurement of Works for Minor Contracts (up to 10 Million)- ICTAD/SDB/03
2. Procurement of Works for Higher Values (between 10 – 100 Million) – ICTAD/SDB/01
3. Procurement of Works for Major Contracts (over 100 Million) – ICTAD/SDB/02
4. Procurement of Works for Design & Build Contracts – ICTAD/SDB/04

Electrical bid estimation process involves various types of data collection, analysis and interpretation. Therefore whichever the contract type is selected there are standard set of documents which have to be provided when calling for bidding those are,

1. Bid Notice
2. Instruction to Bidders [4, sec1 ]
3. General Condition of Contracts [4, sec 3]
4. Special Condition of Contracts
5. Form of Agreement [4, sec2]
7. Special Specification of Works
8. BOQ and Schedule of Rates [8, sec7]
9. Sample and Guarantees
10. List of Drawings [4, sec8]

Our quoting process is made based on the details given in each one of these documents. For some of the projects the contractor or bidder won’t get the all the documents shown in the above list. But however as long as the total scope of work is covered there is no such obligation to be made by the bidder. Otherwise there has to be made inquires and sorted out the problems related to bidding documents. Another option is to indicate all the inclusive and non-inclusive items in list which will be enclosed with tender submission and there afterwards take into notice in the tender evaluation process.

Each one of these has its own ways to describe the scope of works. It could be location or dimensions of the particular job where professional knowledge will be required to understand by reading through it specially construction drawings, or it could be the standards which should be emphasized by regulatory bodies where you can find especially in the specifications or it could be quantities where those are summarized in bills of Quantities (BOQ). Out of these, there may be special conditions which will be imposed by the regulatory and constitutional bodies where it will be found either on contractual agreements or conditions of contract. In Sri Lanka most frequently used regulatory books for the construction industry are FIDIC, ICTAD and JICA.

QS Should have sound knowledge about each of these because it contains all requirements which should be abided by the law in both parties which means contractor and the client. As in the FIDIC [5], almost all the conditions and obligations required to fulfill by both parties are listed and explain. This is actually to minimize dispute over BOQ, specifications, tender drawings interpretation and also engineer’s duties and authority in employer side, contractor general obligations, staff and labour management, plant, material and workmanship management and so on. Having sort of general knowledge of bid estimation for electrical installation work, it is useful to have touched upon general methods of estimation for typical installation work which can be found in the industry. Those are generally [6].
A. Based on bills of firm quantities
B. Based on bills of approximate quantities
C. Based on drawings and specifications
D. Based on schedule of rates
E. Based on cost reimbursement

Those items A to E have its own advantages and disadvantages as described in [6]. Therefore, the final outcome of this estimation is combination of all aspects that has been discussed so far and sometime it would be more than when expertise knowledge involved.

1.2. Problems of current approaches

Selection of Electrical Contractors for electrical installation projects specially in building construction projects are mainly followed up with competitive bidding. Selection procedure is established based on not only final cost of bid proposal but various qualitative and quantitative aspects are also taken into consideration.

Therefore, generally expertise involvements for estimation of major projects are very important in the context of quantity surveying because pricing of works should be in the right scope and errorless. However in general almost all the contractors are willing make improvements on this context since there is no such mechanism to overcome this problem or minimize the effects of bad estimation. Some of the common faults that can be found in estimation are shown below.

i) Incorrect identification of scope of work
ii) Incorrect Material take off
iii) Calculation errors
iv) Lack of prediction for material cost fluctuations
v) Lack of consistency of making good decisions

In fact, prediction for material cost fluctuations are different topic that will be lead up to commercial risk analysis. However when time durations between bid offer submission, awarding and project implementation are considered. Longer the duration, probability of the risk of fluctuations will be high. Therefore, commercial risk analysis such as nine
basic rules of commercial risk analysis [7] has to be conducted and this context is not going for that far. Therefore obviously this is one of the leading current issues in bid estimations as well. This context will not be considered in this research report and let the validity period of the bid proposal be under certain time period where no major fluctuations won’t be entertained or executed.

In the project management point of view, nobody should be liable for taking the responsibility of having these types of drawbacks. Even expertise involvement is made 100%, contractors cannot expect the solution by eliminating aforesaid issues. Since the process is totally depended on human brain involvement. Mistakes and avoidance can be generated at any time because human brain has limited working memory and get tired then slow in recalling information. In fact, [8, page 8] humans cannot hold vast amounts of structured information with faultless recall, have slow libs, cannot input or output information quickly.

The concerns exposed above are in generally identified in the process of estimation. At the same time, almost all the estimators used conventional Microsoft Excel software as the software base for all the calculation works. Therefore if you find bid proposal having more than thousands of items it becomes more difficult to go along each and every item by using Excel. This is because every item has to be link from the rate analysis to final BOQ rate including Markup and other settings. Therefore, mistakes that can be generated during this data base manipulation are also considerable and cannot be tracked easily if you find unacceptable final bid value.

Therefore, conceptually there has to make some improvements in the bid estimation system in such a way that the competitiveness of the final proposal should be entertained. Otherwise the whole process is in vain.

As a summarization, the problem is confined to a single figure so that the whole story will be explained as follows.
According to the Figure 1, there are two solutions to overcome this issue. First one is to hire more expertise so that the full load will be shared without overloading each one of expertise or second one is to implement a knowledge base system in which the use of human expertise would be minimized with an increase of the accuracy and competitiveness of the bid proposal.

Therefore, Second option will obviously be taken as the viable solution to the existing problem and scope of this research is to find a sound system where human expertise role is converted to knowledge base system and finally developing the same in software base so that the final target will be achieved. Software like SCBMD (Strategically Correct Bid/No bid and Markup Decision) has been developed recently and in that research [9], a model used as the basis for determining right decision on going for the bid or no bid when an invitation has been received. SCBMD will make decisions based on that the estimation of bid proposal is 100% correct and always dealt with analysis of the mark up percentage of a particular bid proposal. Here in this research, it is mostly focused on making the right bid proposal in terms of estimating right quantities and the scope of works. Of cause there

Figure 1 – Bid Preparation Process
is another research work which has been developed recently. In that [10] this study proposes a novel model for quickly making a bid-price estimation that integrates a probabilistic cost sub-model and a multi-factor evaluation sub-model. The cost sub-model, which is simulation-based, focuses on the cost divisions to save estimation time. At the same time, the multi-factor evaluation sub-model captures the specific factors affecting the cost of each cost division.

1.3. Motivation

After being exposed to construction field in electrical installation works for more than 8 years, there was a serious curiosity to make the electrical contractor be safe in bid estimation, because the most of the companies in Sri Lanka have not been conducted any research on making reliable bid estimation. However cause of the delay in making the improvements in the estimation process is still not clearly identified but there are so many concerns among the QS people who are willing to have a more reliable method to work with.

In general, QS persons didn’t have opportunities to being exposed to electrical engineering during their study. Therefore, time taken to be an experience electrical estimator is very high. Then companies have to take risk on their tender proposal and should be incorporated with experience electrical engineer to overlook the tender proposal. Therefore, it is wise to have sound system in which it is included expertise experience, so that the tender proposal would be more reliable and more competitive.

During my working period, I have experienced that the most of the electrical contractors suffers bad outcome at the final stage of project due to unreliable bid estimation. It is because, at the tender stage, lots of mistakes would have done which are unnecessary and can be prevented.

Therefore, it is obvious that one can make the risk involvement in electrical bid estimation down to as minimum as possible that will helps the entire industry in Sri Lanka to be more productive in the future.
1.4. Objectives

a) Introduction of Expert system for Electrical Bid Estimation in the Electrical Installation of buildings
b) Development of software based user interface to enhance the bid estimation process which is based on the expert system for electrical bid estimation.
c) Case studies with sample estimation and make sure the reliability of the process and methodology

1.5. Thesis Outline

Chapter 1: this covers some of the aspects related to bid estimation in relation with the electrical installation. At the same time it includes problems in current approaches and its future innovation together with the expert system.

Chapter 2: in this section, reader will get some knowledge about expert system and it present usage. And also how expert system is applied to electrical bid estimation by using rule based system.

Chapter 3: covers the user interfaces used for taking inputs relevant to a particular project and the final output based on the software development.

Chapter 4: under this section, competitive bid estimation is discussed, the developed expert system as described in the previous section is applied for electrical bid estimation. Then discuss about its results and advantages over the conventional system.

Chapter 5: conclude the research project by introducing pros and cons of proposed system and future trends of expert system application in relation to electrical bid estimation.
Chapter 2: Expert Systems Approach for Electrical Estimation

2.1. Introduction to Expert Systems

Development of ES could be seen in liaison with the technological improvements of the computer architecture and served almost all the fields where human could get the benefit of it specially manufacturing industry, medical, transportation, banking, communication etc.

Because of the changing environment from ordinary use of methods to advance technologies such as computer simulated programs, estimation work is also found to be an interest field for use of knowledge base system as described in [8, page 2]. It says “with development of inexpensive computers and information technology, more of this knowledge would come into the public domain and the mystique surrounding the expertise would begin to disappear. In time this would lead to demise in the status of such professions”.

Further [8, page 8] has noticed how the direction of development of ES system at the early stage. as “the harnessing of computer based information technology – perhaps the greatest motivator for change has been the development of the computer, together with a massive drop in price which has put it within reach of all. Alongside this development has been a revolution in electronic communication providing the means for machines to exchange of information is close to competition. The professions, especially those who operate as a team, can ignore this development at their peril. At the moment there appears to be a series of ad hoc developments. At some stage a formalized system, into which all can refer and relate, needs to be constructed. It will need to identify the means of integrating information between models, processes, professions and clientele.”

When it comes to describing the ES in a way that one can ask “what is an expert system?” generally the better answer for this is as in the [11, page 2] “Expert system (ES) are computer programs that try to replicate knowledge and skills of human experts in some area, and them solve problems in this area (the way human experts would)”
In general, [12, page 19] the need for ES is necessitated by the limitations associated with conventional human decision-making processes, including:

1. Human expertise is very scarce.
2. Humans get tired from physical or mental workload.
3. Humans forget crucial details of a problem.
4. Humans are inconsistent in their day-to-day decisions.
5. Humans have limited working memory.
6. Humans are unable to comprehend large amounts of data quickly.
7. Humans are unable to retain large amounts of data in memory.
8. Humans are slow in recalling information stored in memory.
9. Humans are subject to deliberate or inadvertent bias in their actions.
10. Humans can deliberately avoid decision responsibilities.
11. Humans lie, hide, and die.

At the same time, there are remarkable benefits associated with ES and it can be described as [11, page 19-20]

1. Increase the probability, frequency, and consistency of making good decisions
2. Help distribute human expertise
3. Facilitate real-time, low-cost expert-level decisions by the non expert
4. Enhance the utilization of most of the available data
5. Permit objectivity by weighing evidence without bias and without regard for the user’s personal and emotional reactions
6. Permit dynamism through modularity of structure
7. Free up the mind and time of the human expert to enable him or her to concentrate on more creative activities
8. Encourage investigations into the subtle areas of a problem
There are 3 main sections in the expert system structure [12, page 17] those are,

1. Knowledge base consists of problem-solving rules, procedures, and intrinsic data relevant to the problem domain.

2. Working memory refers to task-specific data for the problem under consideration.

3. Inference engine is a generic control mechanism that applies the axiomatic knowledge in the knowledge base to the task-specific data to arrive at some solution or conclusion.

Complex decisions involve intricate combination of factual and heuristic knowledge. In order for the computer to be able to retrieve and effectively use heuristic knowledge, the knowledge must be organized in an easily accessible format that distinguishes among data, knowledge, and control structures. For this reason, expert systems are organized in three distinct levels:

Even if there are several types of methods where ES can be developed, our main concern is about Rule-Based Diagnostic Expert Systems [13] on which proposed bidding estimation system is based on. Basic structure of a rule based system is shown in Figure 2.

![Figure 2](image-url)  
**Figure 2** Basic structure of a rule-based expert system
Rule-based expert systems have a wide range of applications for diagnostic tasks where expertise and experience are available but deep understanding of the physical properties of the system is either unavailable or too costly to obtain.

In the rule-based systems, knowledge is represented in the form of production rules [13, page 52]. A rule describes the action that should be taken if a symptom is observed. The empirical association between premises and conclusions in the knowledge base is their main characteristic. These associations describe cause-effect relationships to determine logical event chains that were used to represent the propagation of complex phenomena. The general architecture of these systems includes domain independent components such as the rule representation, the inference engine and the explanation system.

If it is brought forward some of the efforts made for use of the expert system in similar applications. [14] Aeronautical systems division of air force institute technology in USAF had done research on the development of an expert system for software cost estimation whose scope covers with weapon system development cost estimation. In that, (COCOMO) Constructive Cost Model had been developed and used for software development by using expert system.

2.2. Electrical Estimation by an Expert Systems
An expert system is obviously incorporated with a knowledge base system to a certain extent. The knowledge base can in fact be developed by understanding the task and scope which are covered in the bid estimation process and the expertise input for the same other than the normal procedure.

2.2.1 Identification of Expertise Role
What are behind the expert mind? - Other than the conventional estimator, expert person has attained following subjects with a specialized analytical and good decision making skills.
(i) Estimation Procedure
(ii) Identify relevant material and labour depending on the scope of work
(iii) Knowledge of market prices of materials and labour and its fluctuations.
(iv) Value added areas where the final proposal would make more competitive.
(v) Judgment of competitiveness of the final bid proposal.

2.2.2 How to establish the knowledge base

Development of knowledge base can be started with identifying the expert role thoroughly. According to the details of the basic structure of the rule based system, it is required to summarize the types of inputs which are required to get the final bid value through a series of data manipulation procedures. Therefore, inputs can be found several ways where usually those are the details getting from the bidding documents, meeting correspondences and any other instructions. Figure 3 will be further simplified version of knowledge base system where inputs are clearly described.

In the construction field, there are three main units of calculations. Those are material cost, labour cost and overhead and profit. These items to be evaluated in all the series of jobs listed in bills of quantities and all of them should be governed by the inference engine.

Figure 3 – Proposed Knowledge Base System
Therefore, the inference engine can be called as heart or the main part of this expert system. This will cover the procedure of estimation, data acquisition, data processing and data manipulation up to the final output according to rules set up by the expert system.

Rules make the system in operation, if one rule is fired, then according to the inference engine setup. There are so many rules will be generated. Therefore this process will continue again and again until the final solution comes.

### 2.2.3 Critical tasks associated with experts

Now identification of the importunacy of having expert system for bid estimation is shown in figure 4 below. According to that, most critical items can be identified as follows.

![Figure 4 – Simplified estimation procedure](image-url)
(i) Identify material involvement per each item – expertise can quickly react to the change in description or change in the scope of work by adding or removing types of material required and quantity of material required.

(ii) Identify labour involvement per each item – in order to value for labour input for particular item. Expertise can always predetermine the activities involved in a selected scope of work or a job. Therefore, this is also one of main skill that the expertise has.

(iii) Material take off from the drawings – in the construction drawings there can’t be shown all the details required for series of jobs as stated in the bill of quantities. But expertise has the skills to get the important material take off depending on the electrical item selected and predict evaluation of items that can be seen in the drawing. If the selected item is considered under lump sum rate other than measure and pay, he has to include all the necessary items which are not available in the drawings or specifications. This is again very important skill that has to be developed with the experience.

(iv) Verify overhead requirement for the project – this is again in line with the experience gained on similar applications. Expertise should be always able to decide supervisory strength, other expenses such as transportation, accommodation, infrastructure facility etc. depending on the project capacity and period.

Therefore, above critical items have to be deeply analyzed so that the knowledge base system will be comprised with all the relevant data input.
2.2.4 Expert system requirements

Development of the knowledge base system based on the expertise role can be listed as following categories. Therefore, the achievement of final objective is mainly in line with the development of those categories.

(i) Implementation of static knowledge
(ii) Flow chart interpretation
(iii) Implementation of dynamic knowledge
(iv) Inference engine (software development)
(v) User interface

Therefore, implementing above categories one by one will lead to get final outcome which is “expert system for electrical bid estimation”.

2.3. Development of the Knowledge Base

Data acquisition is the starting point of developing a knowledge base system and after making the field study related to electrical bid estimation process. It has been identified that the whole process can be subdivided to five sub divisional areas. Those are,

a. Contractual Data collection from Bid documents
b. Scope of Work identification from BOQ, specifications and Drawings
c. Additional data related to installation type, building type and site location
d. Material cost calculations
e. Labour Cost calculations
f. Overhead and Profit calculations
2.4. Development of the Inference Engine of the Expert System

According to the expert system development through the data acquisition, inference engine will play an important role to make the final outcome. To do that, it is required to identify expert role on doing estimation in electrical installation work. In fact, there are 5 sub-divisional sections so that can be simplified the work in total. Those are,

i) Bidding documents related data manipulation
ii) BOQ documents related data manipulation
iii) Findings from the site visit
iv) Material & Labour cost evaluation
v) Overhead & Profit cost evaluation

The figure 5 shows the usual method of evaluation procedure in relation to the bidding documents data manipulation which is carried out by the expertise.
Basically this process is required to check that all the correspondences related to bid documents are in order. Generally expert QS has to make sure the bid that is going to be estimated is a valid bid and also it is required to keep track on supportive documents requirement as per the tender conditions and satisfy the level of prequalification. These are very important aspects to be checked before going to start bid estimation. If contractor is not eligible for quoting for the tender and then it is no use of doing so. Items to be checked in bidding document data manipulation are to be followed as shown in the figure 5. Main considerations are those a) Bidding documents with necessary details, b) preparation of bid security correctly, c) signing of bid documents and d) attachment of supportive documents.
This is sort of routine check that every QS usually is doing to check whether BOQ, specification and construction drawings are coincide with the same scope of work. If there is any mismatch on any item. That should be cleared first. Actually bidders are always getting a chance to express their disputed item during the pre bid meeting.

Items to be verified during BOQ related data manipulation are shown in Figure 6. Important items are generally a) details are clear in BOQ, b) BOQ soft copy is available, c) BOQ and construction drawings are tally and d) BOQ details are tally with specification.
Location of installation work that has to be carried out is vital for QS because it define all the concerns about overhead calculation which means overhead in relation to transportation of goods, accommodation, and site staff requirement etc. flow chart in figure 7 is highlighted general set up that is followed by an expertise.

Site related data is very important part to make sound estimation. Main concerns of the estimator that should take care of are shown in the chart in steps. Those are, a) allowance for travelling cost, b) allowance for healthcare, c) allowance for accommodation, d) working condition of the site etc. this is again one of the main starting points to establish the rules which will be the bottom line of expert system development.
Material cost calculation is main part of the bid estimation process and when it comes to expert system analysis, this involves various type of concerns in order to get right direction to show in a flow chart diagram. As in the figure 8, general view point of the expertise is considered and it covers the areas from material selection, material take off, and quantifying according to the scope of work set up in the BOQ, specification and construction drawings. Actually this contains 2 parts and obviously second part is shown.
below these two flow charts are linked at the item of “Sort list BOQ items same rate according to drawings”.

The above flow chart is basically constructed based on point wiring application. This is the most common item that every QS has to follow. But always come across certain errors as always. Typically this structure can be implemented to other type of categories for example. Generator installation work, transformer installation work as discussed in the software development section.

Figure 9 – Material, Labour & overhead calculation procedure-2
Flow chart diagram shown in figure 10 will continue to with labour cost calculation. This implies general procedure of accounting labour requirement for a particular job. Actually QS should keep records of labour costs and update with time to time. If sub contracting work is preferred, there are several alternative to select best option for this evaluation. Finally these flow charts are used to build up rule based system as described in expert system. Then rule based system will implemented on software based user interface system. However some of the aspects are not directly addressed in this research since it will lead to another research. For example profit setting is totally differred according to nature of the organization which is going to bid and management point of view. Decision support tools have been introduced for bid markup settings as in [15], a case-based reasoning model (CBR) has been developed to estimate the risk, opportunity and competition ratings, therefore markup setting is not discussed in this research work.
Rule based expert system is always come up with “if” and “then” rules. For single type of data analysis, there may be series of rules are incorporated. Therefore, the following rules are developed based on the flow charts as described above.

Now the following schedule shows simple rule based system developed for bidding documents data analysis. In fact, though the final outcome through this process is an expert system which is in software base and operated by taking inputs from the user through user interfaces. All of ‘if’ and ‘then’ rules are not shown this table. This generally gives the basic direction of how the things are developed throughout the cause of this process.

<table>
<thead>
<tr>
<th>Checking Items related to Bidding documents</th>
<th>Action to be done</th>
<th>Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bidding documents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Bid Notice</td>
<td>Check the documents are available</td>
<td>1. if there are available, add to database</td>
</tr>
<tr>
<td>b. ITT - Instructions to Bidders</td>
<td>or removing information.</td>
<td>2. if there are instruction errors, request clarification.</td>
</tr>
<tr>
<td>c. GOC - General conditions of contract</td>
<td>or insufficient data.</td>
<td>3. if there are insufficient data, Client clarification.</td>
</tr>
<tr>
<td>d. GOC - Special conditions of contract</td>
<td>or excessive details</td>
<td>4. if there are excessive details, remove.</td>
</tr>
<tr>
<td>e. Final contract</td>
<td>or unfulfilled requirements</td>
<td>5. if there are unfulfilled requirements, some prequalification.</td>
</tr>
<tr>
<td>f. General specifications of work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Other references</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. Financial Statement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Company Profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Prequalification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Check prequalification is satisfied</td>
<td>1. Prequalifications are satisfied</td>
<td>Check prequalification.</td>
</tr>
<tr>
<td>b. BDO Certification</td>
<td>Check prequalification is satisfied</td>
<td>Check prequalification.</td>
</tr>
<tr>
<td>c. Bid Security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Other references</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Financial Statement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Company Profile</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Prealities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Terms of reference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Scope of deliverables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Specifications of deliverables</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Scope of the contract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Scope of Lump sum items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Submission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Add list of items applicable to Prequalification</td>
<td>Check documents are compiled correctly</td>
<td>Bid documents having correct prequalification.</td>
</tr>
<tr>
<td>b. Prequalification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Description of items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Compatibility with Construction Drawings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Any deviations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Clarifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Clear all clarification immediately</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Selection of rules on bidding document related data analysis
After go through the bidding data collection, the next move is to BOQ documents related data analysis as discussed previously in flow chart analysis. In the same way, rules will be represented in this section in ‘if’ and ‘then’ as shown below.

<table>
<thead>
<tr>
<th>Checking items related to BOQ document</th>
<th>Action to be done</th>
<th>Rules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer Installation</td>
<td>Categorize types of BOQ items and save in excel file</td>
<td>If selection of type of items in (a) to (i)</td>
</tr>
<tr>
<td>Generator Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power point wiring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lighting Point wiring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fan point wiring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolator/FFJP point wiring</td>
<td>Specification details are available</td>
<td>Insert brand of each material data</td>
</tr>
<tr>
<td>Feeder cable laying</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distribution board installation</td>
<td>not following brand are not compulsory</td>
<td>Select most recommended and cost effective material types</td>
</tr>
<tr>
<td>Light fitting installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cable tray, trunking &amp; Ladder installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lightning protection system</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earthing System</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Material Pricing                      |                   |       |
| Cables                                | Get names of materials and insert market prices | Get brand and size of material from each selected category | Insert material price for each item and save in separate Excel worksheet |
| Conducts & accessories                |                   |       |
| Receptacles                           |                   |       |
| Tray/Trunking and Ladder              |                   |       |
| Distribution Board                    |                   |       |
| Others                                |                   |       |

| BOQ Item Selection                    |                   |       |
| Prepare BOQ by using item categories  | Preparation of BOQ | selected location have various types of category | Insert in separate row in the BOQ sheet |
| Arrange BOQ in locationwise           |                   |       |
| Find types of categories in selected location | Complete the total scope of work | |

| Next Step                             | Go to next step    | BOQ Selection is completed | Go to material quantity input |
| Save data and go to next calculation  |                   |       |

Table 2 – Selection of rules on BOQ document related data analysis
Site information is totally depended on the way data taking for the relevant project. Since the most of the times outsourcing is the best way to get reliable information but the person who involves for this data collection plays vital role for QS. Table 3 shows rules which are formulated based on typical way of doing. Therefore, this table is covered the simple structure for rule based system for site information.

<table>
<thead>
<tr>
<th>Checking items related to Site Information</th>
<th>Action to be done</th>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Location status</td>
<td>Verify all the items &amp; consider them.</td>
<td>Check overhead amount per month of each item.</td>
<td>Insert data in overhead calculations.</td>
</tr>
<tr>
<td>(b) Travelling &amp; Transportation</td>
<td></td>
<td>Items from (a) to (i)</td>
<td></td>
</tr>
<tr>
<td>(c) Healthcare requirement</td>
<td></td>
<td>Details of any item from (a) to (i) is not enough</td>
<td>Add uncertainty factors in overhead.</td>
</tr>
<tr>
<td>(d) Accommodation facility requirement</td>
<td></td>
<td>If any item is provided by other parties</td>
<td>Remove in overhead calculation.</td>
</tr>
<tr>
<td>(e) Working time duration of the day &amp; week</td>
<td></td>
<td>According to condition of contract</td>
<td></td>
</tr>
<tr>
<td>(f) Existing operations effects to working hours</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g) Hindrance for working overtime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(h) Material storing method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Site staff office arrangement</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Building Type:</th>
<th>Action to be done</th>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Newly proposed building</td>
<td>Check whether cost consideration is for refurbishment of old building involved with each item.</td>
<td>Schedule overhead input with removal activity.</td>
<td></td>
</tr>
<tr>
<td>(b) Refurbishment of old building</td>
<td></td>
<td>Building type need special skill categories</td>
<td>Add new rates for labour and staff input.</td>
</tr>
<tr>
<td>(c) Extension of existing building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Removable items</td>
<td></td>
<td>Inusable items are available</td>
<td>Deduct in relevant BOQ item.</td>
</tr>
<tr>
<td>(e) Reusable items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(f) Additional safety measures requirement</td>
<td></td>
<td>Contract requires additional safety</td>
<td>Add in the overhead input.</td>
</tr>
<tr>
<td>(g) Additional tools requirement</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(h) Building type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i) Highrise building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(j) Wide spread building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(k) Hotel, Apartment, industrial, shopping complex</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Unpredictable Factors</th>
<th>Action to be done</th>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unpredictable site condition</td>
<td>Overhead put revision according to uncertainty level</td>
<td>Site information are insufficient, unclear</td>
<td>Add percentage of the overhead setting</td>
</tr>
<tr>
<td>Unpredictable building status</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 – Selection of rules on Site information related data analysis
Rules set up for material cost calculation is main and important part of this expert system, since material cost is mostly covers 60%-70% of the total cost of any project. As far as electrical installation is concerned it would go up to 70%-80% of the total. Therefore, accuracy of material take off should be high level to reach for more competitive bid estimation.

Rules comprising with ‘if’ and ‘then’ are set as above sections. We have to mention about not discussing labour and overhead & profit (OHP) calculations are not developed because labour cost evaluation is depended on factors that are managed by the relevant organization, simply, labour productivity, efficiency, method of sourcing labours, management staff for the labours should be taken into consider as well. The best way of doing overhead calculations is by referring to preliminaries check list [16] and pricing the items that are applicable according to scope of work provided by the tender. Therefore leave it for further references and software development is going to be discussed in the next chapter.

<table>
<thead>
<tr>
<th>Checking items related to Material Cost</th>
<th>Action to be done</th>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>General details related to pricing</td>
<td>check the basic information related to estimation</td>
<td>Identification of the type of the contract</td>
<td>go to material take off</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Identify pricing method</td>
<td>prices are based on knowledge of contract</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Grouping materials according to BOQ item</td>
<td>Classification of materials according to type of electrical items</td>
</tr>
<tr>
<td>Setting Material requirement for the project</td>
<td></td>
<td>Price of electrical items calculated</td>
<td>materials are grouped in classes so that the pricing</td>
</tr>
<tr>
<td>Selection of Price of Materials</td>
<td></td>
<td>Agree prices for material list of items</td>
<td>based on the calculation</td>
</tr>
<tr>
<td>Estimation to manage material suppliers</td>
<td></td>
<td>Calculate material cost for the project</td>
<td>the best price of materials is selected</td>
</tr>
<tr>
<td>Estimation of cost</td>
<td></td>
<td>Consider supplier conditions at time of</td>
<td>based on the project requirement</td>
</tr>
<tr>
<td>Estimation of overhead items</td>
<td></td>
<td>Consider any other expenses related to the project</td>
<td>cost of overhead and get final value</td>
</tr>
<tr>
<td>Profit calculation</td>
<td></td>
<td>Calculate the profit margin</td>
<td>inserted the values and go to markup setting</td>
</tr>
</tbody>
</table>

Table 4 – Selection of rules on Material cost related data analysis
Chapter 3: Software Development

As far as expert system for electrical bid estimation is concerned. The final step has to be made for developing the inference engine. To do that, it has been chosen, “Visual studio 2010” (visit http://www.microsoft.com/visualstudio) and C#. C# is the programming language while Visual studio is the developing environments. Basically it is used windows forms application as the main application type and items which are discussed in chapter 2 are going to develop by using object orient programming methods with Visual studio.

3.1 Data collection in software development

This window form named as Page_2 is used to define the project by requesting from the user about general information. This can actually be used for separating out and identifying the project with the others.

![Figure 11   Data collection – General Information](image)

29
After inserting the data requested about the project that is going to bid, program will copy those details to excel file and can be accessed whenever necessary.

In Window Form Page_3, bidding documents data collections are followed up. These are simply used to keep data recorded and sometimes checking the availability of these documents is necessary in order to go ahead with the preparation of the bid. Otherwise proposal would not be complete.

![Figure 12  Data collection – Bidding document information](image)

Items no 1 to 10 are sometimes needed to be attached in the final bid proposal. This is to make sure that the bidder won’t get any disqualification over the missing documents such as specially ‘bid notice’, ‘form of agreement’ etc. more importantly bid evaluation committee will understand that the bidder have read all the documents well by having relevant authorized signatory in relevant documents.
Figure 13 shows, more elaborated version of window of checking availability of documents. This should be done by clicking the enter button on the respective item in figure 12. After putting a tick as shown in the window, user must click on save button in order to record the data in excel sheet preprogrammed through the software.
After filling all the items in figure 12, again click on the save button shown in the bottom of the same window.

Likewise, next window ‘page_5’ will appear after clicking in the next button and this will guide to ‘prequalification and supportive documents submission’. This is another mistake that usually do by QS, because supportive documents should be submitted together with the bid proposal. Otherwise bid is going to be disqualified.

Figure 14  Data collection – prequalification and supportive documents submission

Types of the supportive documents that are generally requested are listed with this window and need to insert data when each one of the check buttons is clicked. Separate sub-windows forms will be appeared and should be ‘save’ after completing the data. Then results are copied to excel sheet as you click on ‘save’ button before going to the next window.
Then, the data collection from the user is still continuing with the ‘selection of the type of the contract’ as shown in figure 14. When the type of the contract is selected all the cost estimation should in liaise with conditions in relevant to the selected type. For example if the project is going to bid in duty free basis, then all the materials should be considered in duty free rates. Likewise other types are also made to have sort of change in cost estimation methods. Through this software, it will remind the user about the type of contract when the material and labour cost estimation is being done. To do that all those records will stored in the same excel sheet and will automatically recall later on.

![Figure 15 - Data collection – Selection of the type of the contract](image)

Here user has to tick on what is applicable by finding the details through the bidding documents as checked in the user interface shown in figure 12.
User now has most important window as shown in below in figure 16, BOQ information setting is very important and need to have deep consideration before entering data. Why is it so important? User must categorize type of electrical item categories and its sub categories. For example if the user entering data related to item no 3 which power point wiring, there has to be categorized main items for power point wiring which is based on the scope of work. If it is found that there exists any scope change in the same category that will put into new sub category. Like 13A radial circuit, 13A ring circuit or 15A radial circuit are three different scope of work. Therefore, deserve to have separate sub item under power point wiring.

![Data Acquisition BOQ Information](image)

**Figure 16**  Data Manipulation – BOQ information

There are 13 items introduced in this set up and generally covers almost all the items anybody can find in the electrical estimation. However the extra low voltage (ELV) installation is not considered in this expert system. Since those are more close to electronics and telecommunication field and requires different expertise involvements.
According to the BOQ details and scope of work as shown in the specifications and construction drawings, user will define the number of types of transformers. Generally what will see is that user has only to select the type of the transformer, capacity, voltage ratio etc.

This is simplified action as far as expert system is concerned because now user does not need to remind everything required under transformers. Filling of above requirements would be enough for a supplier to quote with a price.

Normally transformer installation is specialized work as discussed in chapter 1. What the QS would do, get a price from the specialized subcontractor and put the price in cost calculations.

![Data Aquisition](image)

**Figure 17** BOQ item categorization – Transformer Installation
This is similar to Transformer installation, but different category. In the same way, contractor gets separate quotations through specialized sub contractors, sometimes fuel pump system and ducting work for flue gas pipe line and hot air duct lines are also come under the same category which is considering single item. But as far as electrical installation is concerned, Figure 18 shows typical information that the expert person will always take into consider.

Figure 18  BOQ item categorization – Generator Installation

Data that must be selected on this window can be taken down from the specification documents. And it is very important to go through construction drawings for more information as well.
Power point wiring is the most recurrent item that any QS will find in their quoting. This will come under item No 3 in BOQ information. The most important thing in this item is to identify number of types of power point wiring throughout the entire installation. This is done by checking type of materials used for point wiring and method of installation. If two locations have different items from the above two types. Then insert 2 types in the point wiring.

When there are several numbers of types are selected. Let’s say 10 types. Then user should enter details of the each item one by one. When one item’s details are selected then click on the ‘save’ button and go to ‘selected item’ and then select the next type. Likewise enter details of each one in this way.

Figure 19  BOQ item categorization – Power point wiring
In the same way, user can insert data of light point wiring, fan point wiring, AC point wiring and Isolator point wiring. Those are kept away from discussion since once the software is being used user can follow up the same method which is described in power point wiring categorization.

Window shown in figure 20 will be opened once click the ‘enter’ button in the BOQ information window. This is for feeder cable laying. Similarly user can set no of types then insert data on each type one by one. In each entering, save button should be click in order to save the data in excel sheet which will be saved in separate sheet.
Item No 9 in the BOQ information is used for setting data related to cable tray trunking and ladder installation. As in the early stage, user should identify different items which are in the same category. This is of course manipulated referring to BOQ and construction drawings. Once the relevant data for particular item can be easily entered since the data is already defined in this window. The data entered will be saved in separate columns in the same excel sheet used to store BOQ information.

User must not forget to click on the ‘save’ button on changing one of types selected according to BOQ details. Selection of the types is generally the same way that power point wiring types were defined. If there is material change or scope of work changed present in the design. User must introduce different types so that each type can be addressed once the final BOQ estimation is done as shown in later steps.

Figure 21  BOQ item categorization – Cable Tray Trunking and Ladder Installation
When stepping down with another BOQ item category, lighting fitting installation is usually called separately and not included with lighting point wiring, therefore, this item is also introduced and sometimes specification is asked only for installation by considering supply of fitting done by the client. Because selection of the good quality brand through the tendering process is bit difficult. But most of the time supply and installation will come under one category.

According to figure 22, prices will be usually called from specialized suppliers. Therefore, prices will be taken after sending the details selected in each type and ask quotation accordingly.

Figure 22  BOQ item categorization – Light Fitting Installation
Pricing for electrical power panel installation is included with certain technical specifications and normally QS person need to have certain knowledge in electrical engineering to do that. However in this window, it is simplified with use of expertise knowledge and by inserting material components one by one will lead to conclude for final bidding.

![Data Acquisition Window](image)

**Figure 23  BOQ item categorization – Distribution Board Installation**

In here, all the types of breakers, enclosures, and accessories are taken into consider and more importantly, it is very less probability to miss material during the estimation. Since user will follow through predefined frame work. That is also benefitted. Before going to work with this window, it is really need to get an idea of doing the work, because there are lots of items which are involved in a single panel. For example if there are several numbers of moulded circuit breakers in the panel. User should individually address to each one of these and set the details and click on save button and then move to next item. Likewise other items are also taken care of.
The last item that is going to discuss in BOQ item categorization is lightning protection system. In generally it comes in item rate. However, QS should understand the material quantity used for a particular installation and costing accordingly. Costing of these items is bit easy since material types are typical so it is enough to have an update in material cost in order to be finalized the costing. Finally you can find earthing system as the final item to be categorized in BOQ information and it is somewhat similar to this item. Therefore, once the user get used to the way that should be estimated. Those items can be finalized without much effort.

Figure 24  BOQ item categorization – Lightning protection system

Refer the electrical bid estimation software for more information about categorization of electrical items. After categorization of all types of electrical items as discussed previously, now it remains to fill unit prices of selected materials in each category. That will be discussed in the following window.
Now being progress with the software, in this stage, basic unit pricing will be done for main categories. For example, if power point wiring is selected in category selection combo box. All the sub categories under power point wiring are appeared in the material list information box and automatically unit types will be also appeared accordingly in unit box. Then by clicking edit button, user can enter pricing details in relevant to each item that will be appeared in separate box.

![Basic Material Pricing](image)

**Figure 25  Basic material pricing**

After setting the unit prices of all the main categories, user now ready to go ahead with final BOQ estimation. The important this in here that user still not set the actual quantities in any type. This is good advantage because even in the same scope of work, material quantities can be changed. Therefore, user has much opportunities and flexibility of doing the estimation work properly.
Figure 26 shows the window that will set the BOQ estimation process. Actually it is a kind of reprinting BOQ given in the tender stage with more details and later user can price each and every one very easily. After selecting total no of BOQ items which should be more than the items appeared in tender BOQ, go to next button and select the item category relevant to the original item. Now user can load any item category which is set during the item categorization process. When the user make progress with BOQ preparation item numbers automatically update and save in a separate excel sheet in the same file.

![BOQ Item Selection](image)

Figure 26   BOQ item selection-1

The button as shown in ‘go to overhead calculation’ can be clicked after entering the entire BOQ item one by one. Window that will appear by clicking the next button will be discussed below.
As you can see, BOQ no will be shown in a text box and it will automatically update when moving one to another. Generally user can write the description for the particular BOQ item if wants. Actually this option is introduced in the event of preparing BOQ instead of coping existing one. Then once the user selects the item category and its type, automatically data will load to name text box, unit text box and rate text box. Quantity should be finalized at this stage by clicking on the enter quantity button. QS will can use traditional methods to get material take off details but however all the records will be kept in a separate excel sheet and can be accessed any time to find if there is any mistake.

![BOQ item selection](image)

**Figure 27  BOQ item selection - 2**

Now almost finalized the material cost calculation and then labour cost input the BOQ quantity have to be entered to complete this work. BOQ quantity means not the material quantity, it is no of items in the same type that is going to use in the BOQ as per site requirement.
Both of the calculations are embedded in a single window so that not only getting the unit rate of the single item category but will be multiplied according the tender BOQ or tender drawing details to get the final BOQ value in order.

Basic material & labour costs are now finalized. Figure 28 shows an important aspect in bid estimation which is overhead calculation. This is one of the main area that use of expertise knowledge is required and but almost all the details are covered in relevant to the electrical installation though this user interface. User must select necessary items which are required throughout the installation period and enter the prices according. When clicking ‘go to next’ button. Data will be stored and added into subtotal and user can select another item by dropping down from the combo box.

![Overhead Calculation](image)

**Figure 28** Overhead calculation
As you can see, user has all consideration for overhead calculation and at the same time profit margin which is going to introduced should be set in the text box shown in the same window. Then user will see the final value with material and labour cost including overhead & profit. Next step before the final BOQ will be seen, mark up setting.

Data manipulated up to now is basic material and labour cost, total overhead of the project. Therefore, finally QS should do is set the mark up values where value for overhead and profit margin should be included in each and individual unit rates. To do that, we set markup values for each main category. Then check the final BOQ value tally with the cost of basic material, labour and OHP. This will be done by the figure 29 as shown below.

![Mark Up Settings](image)

Figure 29  Mark up setting
Now user doesn’t need to go to each item and multiply by markup values one by one. This expert system will do it automatically. Since data base has been implemented in such a way that software will identify each category in the BOQ then multiply them according to the relevant markup setting.

Preparation of BOQ is completed at this point. After setting out markup values as per the requirement of the bidder, user can get the complete picture of the overall estimation. In fact, if user access to the excel file that stored all the details in order to investigate anything that is going wrong during the estimation work as well.

![Figure 30  Final BOQ](image)

This bid estimation software is comprised with some of the aspects that we discussed in the chapter 2 which is expert system approach in electrical installation.
System architecture of the software is always set to manipulate input data in a predetermined logical system. However once the categorized items are set up by the user, it can easily be accessed and offered with lots of flexibility in handling.

Most of the time in Sri Lankan QS would carry out estimation work by using Microsoft excel as the application software. When the no of BOQ items are in large quantity, it is very difficult to track down any doubtful incidences during estimation. This is because cells are manually link so that cost calculations are to be worked out. But Bid estimation software keep information separately as a block for each item category. Therefore, if user will feel some doubtful work out, it will be easily correct by configuring sub categories defined by the user.
Chapter 4: Competitive Bid Estimation

4.1. Application of the Expert System for Competitive Bid Estimation

Application of this software is suitable for all the type of major construction works such as hotels, apartments, offices, commercial buildings and etc. this is useful for electrical contractors and estimators who do sub contract work for main contractors. The concept used in this expert system is very simple. Anyone can get used to it with having little guidance on operation of the software.

Electrical installations which are included with transformer installation, generator installation, all the types of point wiring (lightings, powers, fans, isolators, AC’s), feeder cabling, cable management system, lighting fitting installation, switchgear panel installation, lightning protection and earthing installation, can be estimated through this software. In deed almost all the items are discussed here. Therefore, entire scope of work related to electrical installation is taken into consideration.

As described in the software development section, item categorization is the most important part in this work out. Since BOQ has large no of items but the same items are repeated though out list. For example if we consider about multi storey’s building. There can be the same item in each floor. Then the categorized item will be appeared under each floor sections in the BOQ. Therefore, concept which is used in this bid estimation software reduces time of estimation since repetitive items have been finalized at the early stage.

4.2. Case studies for Electrical Estimation

Case Study 1: electrical estimation for apartment’s project is considered. Refer the Annex 1 for bidding document data related to the project called Oyesters Apartments Project which was held at Colombo 3. Following item categorizations are finalized according to details available in bidding documents.
a. Power point wiring – 3 Nos
b. Lighting point wiring – 02 Nos
c. Feeder cable laying – 07 Nos
d. Cable trunking – 01Nos
e. DB installation – 25 Nos
f. Lighting fitting installation – 02 Nos

Material unit rate input is selected by referring to material supplier quotations and those are presented in item rates calculation in the software. In the final summary sheet, you can find material cost, labour cost, BOQ quantity, markup setting, and overhead calculations and then final BOQ which is generated by the bid estimation software is attached.

Case Study 2: Item categorization for the Club Palm Bay project is summarized as follows.

a. Lighting point wiring – 02 Nos
b. Feeder cable laying – 11 Nos
c. DB installation – 11 Nos
d. Lighting fitting installation – 02 Nos

Refer the Annex 2 for bid estimation results pertaining to BOQ of the club palm bay project.

4.3. Estimation Results and Discussion

This bid estimation software has given the same results that can be achieved by using the conventional methods. In general, calculations are done by using Microsoft excel worksheets in the conventional system. Possibility of making erroneous calculations is pretty much higher than the expert bid estimation software method, because it reduces calculation errors, and increases the confidence of user with lesser operating time.
Representation of the software output has to be further improved, since it is not served much attention for making attractive user interfaces and printing output in a comprehensive way. Results of the bid estimation have been accessed from the both the software and excel data sheet in which all the data is copied and also almost all the relevant details have been covered with the display of standard formatting.

When verifying the values after completing a particular estimation work. Only three aspects should be monitored in order to make sure that the bid estimation will be given the optimum results according to the concerns established by bidding organization. Those are as follows.

a) Need to check defining of item categories according to the scope of work.

b) Need to check quantities and unit pricing of each electrical item category.

c) Make sure that all the BOQ items are covered in the final BOQ which is generated by the bid estimation software.

Therefore, now the final decision can be taken quite easily and confidently since there is no cross checking of each and every item as followed in the conventional procedures. Once the above crucial three aspects are satisfied, all the rest of the work will be assured.

Flexibility of handling with inputs and outputs is much higher than the conventional system. Introducing new item categories after completion of the estimation work, addition of new BOQ item, Overhead cost changes, markup setting changes can also accommodated through this expert system.

As in the sample case study No 1, BOQ contains nearly 200 items where it can further increased depending on the requirement. When recurrence of repetitive items is present, it would be quite easy to handle. Since recalling the same item category is by just selecting of required item and load to the final BOQ.
4.4. Advantages of the Proposed System

More or less advantages of the proposed system are very phenomenal since, it reduces the erroneous data calculation, easy tracking of bidding items, less time consuming than conventional method and increases the confidence of the estimator.

This bid estimation software can be further improved according to customer requirements which are basically introducing new item categories, keeping the material cost data base if preferred and modifying with more attractive user interfaces.

In the conventional method, it used to be a big exercise over data entry and manipulation since the QS has to work with excel data sheets. Actually there are few sheets to be set up initially to enter data such as material cost, DB schedule, Feeder cable schedule, site overhead, cable management, rate calculation and so on. Therefore final BOQ preparation will be done by linking manipulated data available in calculation sheets. Then reconciliation process is enormously time consuming and required lot of efforts.

Therefore, Bid estimation software will overcome those kind of deficiencies and improves the reliability of the bid estimation system in deed. And this concept of bid estimation would really fulfill the next generation standards. More importantly, the person who is going to deal with the bid estimation process doesn’t need be very experience or expert person. As long as the QS knows how to work with this program, estimation from small shopping building to very complex commercial building can be handled quite easily.
Chapter 5: Conclusions

Throughout this research, software for electrical bid estimation is developed by using an expert system application and in summery following discussion will probe into how far this approach would make the successful conclusion for the development of the bid estimation software.

a) What knowledge and heuristics does this electrical bid estimation software have?

As long as knowledge and heuristics used for this expert bid estimation software are concerned, procedure of doing proper bid estimation is obviously stuck to what experts will generally follow. And also step by step data acquisition has set up in a most comprehensive manner throughout this software. In fact, once the QS will decide item categories which are in line with the BOQ. Break down of items will be appeared individually and then selection of capacities can be easily established by ticking on the drop down item list. One of the main advantages of the system is that the types of material required for a particular item category is already defined. Therefore, now user or QS doesn’t need to keep references on doing estimation work from starting to end.

b) Can this knowledge and these heuristics make sense to quantity surveyors who are going to use this expert system program?

As in the above explanation, effort that is applied by the quantity surveyors when using this expert bid estimation software is much more comfortable compared to traditional way of doing the job. Once the job is completed, assurance of final result can be overlook in both ways. If the person prefers to check it in conventional method, that can be done by using excel document in which all the relevant data has been stored or running through the software program and repeat the process with inspecting the data values only. Therefore, of cause this program is really make sense to the quantity surveyor who will be kept in minimum risk on estimation.

Question 3: Do expert system significantly improve the performance of electrical cost estimation?

It is significantly impacted on having expert system for cost estimation process. Unlike the other software base systems which are mainly work oriented and data base
management systems. This expert system features sort of universal system. Though it cannot be applied everywhere. This is a most improved system that can give the best performance in terms of bid estimation.

Question 4: Can the use of expert systems allow cost estimators to solve complex or difficult problems more efficiently?

Complex is in the sense of wide range of scope in electrical installation and difficult is in the sense of having more repetitive cost calculations throughout the bidding process. However this expert system concept will help to narrow down both complex and difficult measures substantially to a minimum level which is expected. Though, this contains further improvements in accordance with customer requirements. Development of this expert system concept on electrical bid estimation will be reasonably viable in deed.

References


