COMPARATIVE ANALYSIS OF THE COST MODELS USED FOR ESTIMATING RENOVATION COSTS OF UNIVERSITIES IN TEXAS

A Thesis

by

YAQUTA FAKHRUDDIN FAQUIH

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2010

Major Subject: Construction Management

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Approved by:

Co-Chairs of Committee,	Zofia Rybkowski
	John Nichols
Committee Member,	Mardelle Shepley
Head of Department,	Joe Horlen

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ABSTRACT

Comparative Analysis of the Cost Models Used for Estimating Renovation Costs of Universities in Texas. (August 2010)

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Co-Chairs of Advisory Committee, Dr. Zofia Rybkowski
Dr. John Nichols

Facility managers use various cost models and techniques to estimate the cost of renovating a building and to secure the required funds needed for building renovation. A literature search indicates that these techniques offer both advantages and disadvantages that need to be studied and analyzed. Descriptive statistical methods and qualitative analysis are employed to identify and compare techniques used by facility managers to calculate the expected renovation costs of a building. The cost models presently used to predict the cost and accumulate the budget required for renovation of a building were determined through interviews with ten Texas-based university facilities managers. The data and information gathered were analyzed and compared.

Analysis of results suggests that traditional methods like Floor Area Method (FAM) is the most accurate, less time consuming, easy to use as well as convenient for data collection. Case-Based Reasoning (CBR), though not as widely used as FAM, is known to facilities managers. This is due to the fact that, if a new type of project needs to be renovated, and the data for a similar project is not available with the facilities manager, a completely new database needs to be created. This issue can be resolved by

creating a common forum where data for all types of project could be made available for the facilities managers. Methods such as regression analysis and neural networks are known to give more accurate results. However, of the ten interviewees, only one was aware of these new models but did not use them as they would be helpful for very large projects and they would need expertise. Thus such models should be simplified to not only give accurate results in less time but also be easy to use. These results may allow us to discuss changes needed within the various cost models.

DEDICATION

To my parents and sister

ACKNOWLEDGMENTS

I would like to thank my co-chairs, Dr. Zofia Rybkowski and Dr. John Nichols, and my committee member, Dr. Mardelle Shepley, for all their help and support in this journey. I would also like to thank Dr. Sarel Lavy and Dr. Jose Solis-Fernandez for their guidance.

Thanks to Apurva Gupta and all my friends for supporting me throughout this course. I want to take this opportunity to thank International Facilities Management Association (IFMA) for helping me gather substantial information related to my research.

Finally, I would like to thank my father, mother and my twin sister for standing by my side during this endeavor.

NOMENCLATURE

FAM	Floor Area Method
JSEM	James Storey Enclosure Method
CBR	Case-Based Reasoning
RA	Regression Analysis
NN	Neural Networks
THECB	Texas Higher Education Coordinating Board
QTO	Quantity Take Off
BIM	Building Information Modeling

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1. INTRODUCTION

1.1 INTRODUCTION

> *Successful deployment of the facilities management function for any major development will depend upon the ability to identify, communicate, and manage opportunities to help support an organization's business objectives at the earliest possible time.*
>
> *-Edum-Fotwe et al., 2003*

Apart from maintenance and repairs of a facility, facility managers are also responsible for forecasting the post-construction costs and managing the budget. As explained by Edum-Fotwe et al. in 2003, cost forecasting if done at the earliest will help support the organization's business. This research deals with the forecasting of renovation costs before the commencement of the renovation and after the construction of the facility is completed.

Cost models are methods/formats/frameworks which need relevant input data to obtain the estimated cost of renovation. Various models are being used to find out the cost of the construction project; however no model can give a perfect estimate due to several uncontrolled factors like change in the design, change in the material cost, to name a few. This leads to constant improvisation of the cost models to get as accurate results as possible.

Traditional methods have been continually revised to get more efficient models like the case-based reasoning models (CBR), regression analysis (RA) models and

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This thesis follows the style of the *Journal of Materials in Civil Engineering.*

neural networks (NN) (Kim et al. 2004). Furthermore, cost models like regression analysis and neural networks have some merits and demerits. However, if both techniques are being used simultaneously, a satisfactory conceptual model can be obtained (Sonmez 2004). Case-based reasoning is another example of a cost model that needs some revision for it to give better output (Wang et al. 2008).

Also, as compared to CBR and RA models, the NN model is slow in establishing the best results since it involves the trial and error process. The CBR model is relatively consistent and easy to update. Hence, it is preferred for long-term use (Kim et al. 2004). A literature search thus indicates that the techniques and cost models currently being used offer both advantages and disadvantages that need to be studied and analyzed.

For practitioners and decision makers, accuracy is not the only criteria for selecting a cost model for cost forecasting. Ease of gathering the data that is required to estimate the cost of renovation, ease of use and speed of the model are some of the other factors that practitioners look for in a cost model (Yokum and Armstrong. 1995). This research aims to identify the merits and demerits of the cost models based on not only the accuracy of results, but also other aspects that the practitioners and decision makers prefer.

1.2 PROBLEM STATEMENT

Many cost models have been developed to help calculate the cost estimate more accurately but are not being used by facilities managers. Obsolete cost models are still being used which do not give accurate cost estimate.

1.3 RESEARCH OBJECTIVE

Investigate the advantages and disadvantages of the cost models being used to calculate the renovation cost of universities to help future researchers in improvising the existing cost models and creating a more competent model.

1.4 LIMITATIONS

i. Data was collected from the facilities managers of the universities located in Texas only.

ii. Interviewees were asked to give information on the projects completed in the past five years.

iii. The space renovated in these projects had an area of approximately 5,000 sq. ft.

2. LITERATURE REVIEW

2.1 INTRODUCTION

Various cost models and how each one calculates the estimated cost, need to be studied to understand the shortcoming of each of them. Cost models are used in the projects that involve new construction as well as renovation projects. The literature review revealed some of the cost models that are developed for such projects.

2.2 COST MODELS USED TO FORECAST COST OF RENOVATION

Cost models use independent variables like quantity and cost of materials, and location index to name a few for cost estimation of both new construction as well as renovation. Hence cost models used for new construction projects are also studied in this research as they can be used in the renovation projects too by changing, eliminating or adding the required variables, depending on the project. Following is the list of cost models:

2.2.1 CUBE METHOD

This first known cost forecasting method which was invented 200 years ago (Skitmore et al. 1990), considers the cost per unit volume and no other factors like the number of floors, architectural style and function (Skitmore and Thomas 2003). Figure 1 shows a schematic diagram that explains the working of cube method.

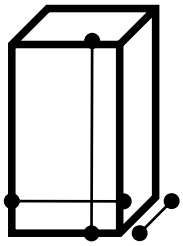

Fig. 1. The Working of the Cube Method

2.2.2 FLOOR AREA METHOD (FAM)

This method was developed in the 1920's, and uses the cost per unit area to forecast the cost of the project (Skitmore et al. 1990). As in the Cube method, FAM also does not consider other details in cost forecasting (Skitmore and Thomas 2003). Figure 2 shows a schematic diagram that shows the working of FAM.

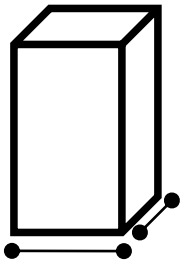

Fig. 2. The Working of the FAM

2.2.3 JAMES STOREY ENCLOSURE MODEL (JSEM)

The James Storey Enclosure Model was developed in 1954 by one of the pioneers, W. James. This was an alternative method to the FAM and Cube method. The storey enclosure method considers factors like the shape of the building, total floor area, vertical positioning of the floor area in a building, storey heights of a building, overall

building heights and extra cost of sinking usable floor area below ground level. However, this method is a single rate method i.e. only one price rate is used in the calculations. The different functions in the building are not assigned different rates. Hence this model does not accurately forecast the cost (Cheung and Skitmore 2006). Figure 3 shows a schematic diagram that explains the working of JSEM.

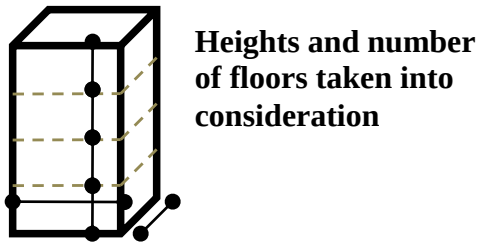

Fig. 3. The Working of the JSEM

2.2.4 CASE-BASED REASONING (CBR)

In this method the problem situation (i.e. the areas to be renovated) is identified. A past case similar to the existing project is found to suggest a solution using that case. The solution is revised taking into account the current economic conditions and construction price fluctuation. A database containing the past cases is prepared and is updated in a timely fashion on the basis of the suggested solutions and learning from this experience (Sonmez 2004). Figure 4 shows a schematic diagram that explains the working of CBR.

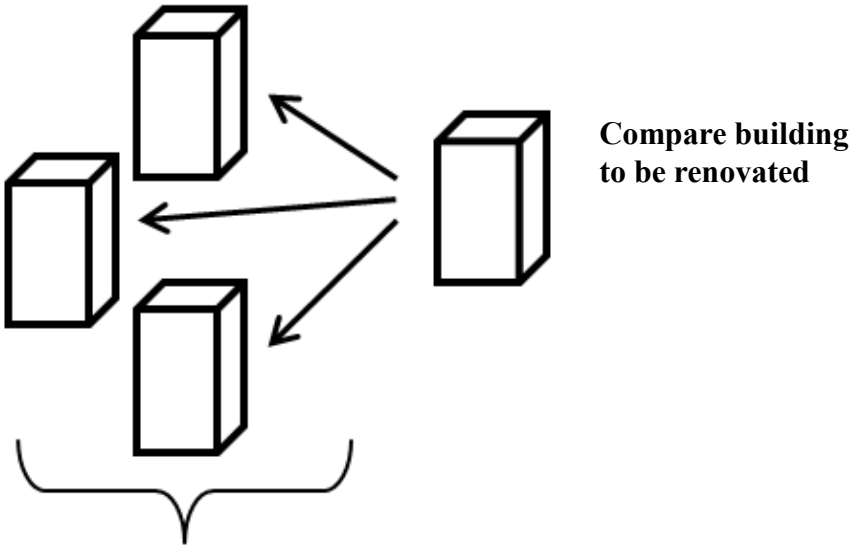

Fig. 4. The Working of CBR Method

2.2.5 REGRESSION ANALYSIS (RA)

This model uses independent variables like location, construction year, building type, number of floors and building technology for cost estimation. A suitable equation is formed using the independent variables to obtain the output as the estimated cost.

$y = ax_1 + bx_2 + c$

or

$y = ax_1^m + bx_2^n + c$

where,

y = Estimated Cost of Renovation

x_1, x_2 = Independent Variables

a, b, c, m, n = Constants

Following are the various regression methods:

2.2.5.1 LINEAR REGRESSION

A linear model regression describes relationships between a response variable and one or more predictor variables by the generalization of a straight line (Hwang 2009).

2.2.5.2 CATEGORICAL REGRESSION

When the data sets consist of categorical data, categorical regression can represent the relationship between a response and its predictors more effectively (Hwang 2009).

2.2.5.3 DYNAMIC REGRESSION

Dynamic regression accounts for the time-lagged relationships by including a time factor, unlike the above regression methods (Hwang, 2009).

2.2.6 NEURAL NETWORKS

This model was developed as an alternative to the regression models. It uses the same input variables as regression model i.e. location, construction year, building type, number of floors and building technology for cost estimation. The difference between the two models being that neural network gives the relationship between the input variables and the total project cost estimate which is the dependent variable (Hwang, 2009). This model gives more accurate results than the case-based reasoning and regression models (Kim et al. 2004).Figure 5 shows a schematic diagram that explains

the cost model.

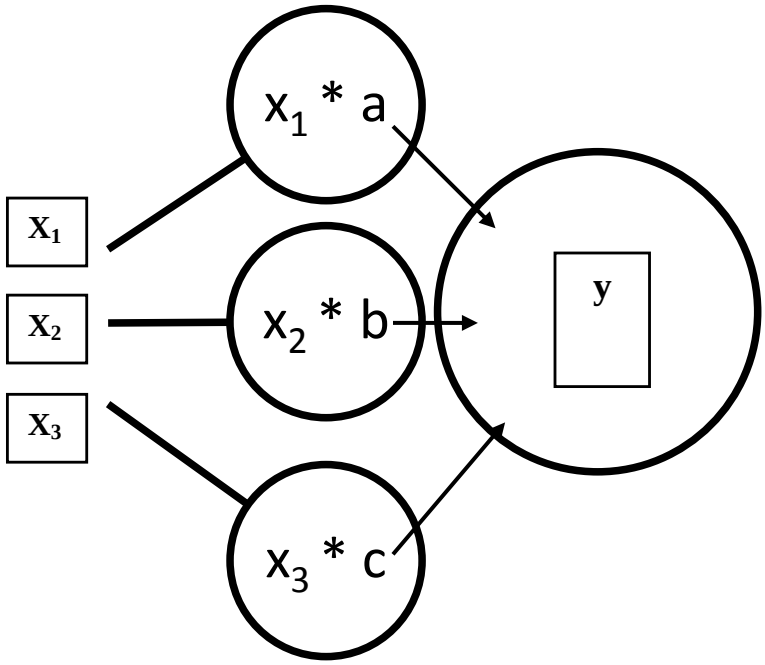

Fig. 5. The Working of the Neural Networks Method (Kim et al. 2004)

The variables required for cost estimating ($x_1, x_2, \ldots$) are fed in the computer. Each variable is multiplied with its weighted importance (a, b, …). The results thus obtained are analyzed and output is obtained as the estimated cost of renovation (y).

2.2.7 TRADITIONAL METHOD

This method includes two stages, namely, investigation stage and design and planning stage. The investigation takes usually 9-12 months while the design and planning stage takes 2-6 months. This makes the entire estimation process very time consuming (Skitmore and Thomas 2003).

2.2.8 16-DIVISION OF MASTERFORMAT AND UNIFORMAT

This is used in the pre-design phase when the scope of the project is not decided. Due to the varying degree of renovation needed, each space is segregated on the basis of the materials used. Cost per unit area is then assigned to all based on the renovation level of each element i.e. minimal, moderate or major. Thus the range of renovation cost can be forecasted for each area (Poremba, 1998). Table 1 shows an example of how each activity is divided into three levels of renovation. Unit cost is assigned to each level for every activity to obtain a range of cost required to renovate that area.

Table 1. An Example of Division of Elements into their Extent of Renovation (Poremba 1998)

INTERIOR RENOVATION		
MINIMUM EXTREME	MODERATE	MAXIMUM EXTREME
Light Demolition	Between	Full Demolition
Minimal Doors	Between	All New Doors
Minimal Partitions	Between	All New Partitions
Paint only New Door and Partitions	Between	Paint All Doors and Partitions
Replace 25% of Floor Finishes	Between	All New Floor Finishes
Replace 25% of Ceiling Finishes	Between	All New Ceiling Finishes
Reuse Most Specialties	Between	All New Specialties
Reuse Most Built-ins	Between	All New Built-ins

2.3 CRITERIA FOR COMPARISON OF COST MODELS

Researchers believe that accuracy is the main criterion for selecting the best cost model; however, a survey done by Yokum and Armstrong in 1995 shows that ease of interpretation, ease of use, ease in getting data, credibility, and speed top the list of the

criteria for selecting the cost models (Yokum and Armstrong 1995). Practitioners rank "ease of use" as the most important criterion (Witt and Witt 1992), while "cost savings and time" as third (Carbone and Armstrong. 1982). This concludes that while developing new forecast techniques, accuracy, ease of use, ease of interpretation, and flexibility should be considered (Yokum and Armstrong 1995). Hence in this research, apart from accuracy, other factors like time, ease of using the model and ease of data collection are also considered to recognize the advantages and disadvantages of the cost models.

3. RESEARCH METHODS

3.1 VARIABLES

The techniques and cost models currently being used by facility managers to calculate the expected renovation costs of a building were identified and compared in this research. These cost models were determined by interviewing the facilities managers of universities in Texas. The telephone numbers of the facilities managers were obtained from their university websites. The parameters that were ranked as the most important criteria for selecting a cost model were used to determine positive and negative points of the cost models. The parameters are “Accuracy”, “Ease of Use”, “Ease of getting data” and “Speed”.

3.1.1 ACCURACY

Accuracy of the cost model is inversely proportional to the difference between the estimated and actual cost. The lower the difference, the more accurate the cost model is. Accuracy can be determined by finding out the Percentage Error (E) by using the formula-

$$E = \left| \frac{C_e - C_a}{C_a} x\ 100 \right|$$

where,

C_e = estimated renovation costs,

C_a= actual renovation costs.

3.1.2 SPEED

The speed of cost model is how fast a cost model can calculate the renovation cost. Participants were asked about the time taken for the cost model they used to calculate the renovation cost.

3.1.3 EASE OF USE

Cost models along with giving accurate results, must also be easy to use. In the interview, the facilities managers were asked to rate the cost models as “very easy”, “easy”, “difficult” or “very difficult” on the basis of their ease of use. Also the terms “very easy” and “very difficult” were defined so that the results were standardized.

Very easy – Anyone in the department can use the cost model to estimate the renovation cost.

Very difficult – Only a few trained people can use the cost model to estimate the renovation cost.

3.1.4 EASE OF GETTING DATA

Each cost model uses data i.e. independent variables to calculate the cost of estimation which is a dependent variable. Some data like area, height of the building and number of floors can be easily obtained from the as built drawings or by mere observation. Some data are difficult to obtain like anticipating additional space required due to staff growth. Such data cannot be obtained directly but need some study. Facilities managers were asked to rate the cost models as “very easy”, “easy”, “difficult” or “very difficult” based on the ease of getting the data required by that cost model to

calculate the cost. Very easy and very difficult were defined so that the results were standardized.

Very easy – The data can be obtained directly from drawings/observation.

Very difficult – To obtain the data, some study and analysis is needed.

3.2 QUESTIONNAIRE

After receiving approval from the Texas A&M Institutional Review Board, ten facilities managers from various universities in Texas were interviewed. Below is the list of questions that were asked.

1. What approaches or methods are used to calculate the cost for renovating a building or a part of the building in the university?

   (This was an open ended question so as to get information on all the techniques used by them for cost estimation.)

2. What do you think is your average percentage error when estimating the cost of renovation?

   If asked the meaning of percentage error, the interviewee was given the following formula:

   $$\text{Percentage Error} = \left| \frac{C_e - C_a}{C_a} \times 100 \right|$$

   where,

   C_e = estimated renovation costs,

   C_a = actual renovation costs.

(The percentage error will give the accuracy of the cost models. The higher the percentage error, lesser is the accuracy of the cost forecasting model and vice versa.)

3. How much time does it take on an average to calculate the cost of a renovation job?

   (This would give us information on how time consuming it is to use each model.)

4. How difficult do you think it is to use each cost model?

   (This would help identifying whether simpler models are used more often due to the ease of use. If yes, then should the newer complex models be simplified to obtain accurate results as well as be easy to use?)

5. How difficult is it to gather the data required by each cost model?

6. Have you heard of or do you use cost models like Regression Analysis and Neural Networks?

4. FINDINGS

4.1 INTRODUCTION

The size of the universities is defined by the number of students registered in that university. Accordingly they were categorized as:

Small : 0 to 10,000 students

Medium : 10,001 to 30,000 students

Large : 30,001 to 50,000 students

Out of the ten universities, four were from the northern part of Texas, two from the eastern part and the remaining three from the southern part.

Following is the description of the responses from the facilities managers.

4.2 INTERVIEW 1

Interviewee : Mr. A

Post : Facilities manager

University : University A

Size : Large

1. Following were the three types of cost estimation methods used for renovation projects as per Mr. A:

   Cost per square foot method is used in which the local costs of materials, the year in which the renovation is taking place and the range of costs according to the function of the space are considered. The year in which the renovation is taking place is important as it helps increase or decrease the unit cost based on the escalation rate and price hike. This method is similar to Floor Area Method.

Quantity take-off is done by an architect and an engineer. They are called to work out the preliminary cost estimate. They study the building or a part of the building that needs to be renovated and come up with a very accurate estimate.

The area to be renovated is compared to the previous similar cases to find out the approximate cost of renovation. This method is Case-Based Reasoning. The cost estimates and the actual costs of renovation of all the projects are updated in a database. If any similar project is to be renovated, the previous data can be obtained from this database and modified according to the change in the market conditions.

2. Accuracy - Though Mr. A was not able to give the percentage value as it was against the policies of University A, he said that in most of the cases the cost estimated turned out to be lower than what the actual cost would be.
3. Speed - The cost per square foot method is the fastest way of getting a cost estimate and takes around two days. Calling the architect and engineer to do the quantity take-off and cost estimation is the most time consuming out of the three methods mentioned above and takes about a week.
4. Ease of use - The cost per square foot method is very easy (1) to use as it requires just the unit cost and the area to be renovated. While other methods require an in depth study to get the results and are difficult to use (3).
5. Ease of getting the data required in estimating the cost - The data can be easily gathered in all the three cases. The cost per square foot method just requires the area which can be easily (2) calculated from as-built drawings. When the architect and engineer come in to determine the preliminary estimate the data is directly obtained

by observation and/or from the drawings (2). Case-based reasoning i.e. the method which involves comparison of the project to past cases is also easy (2) as they have a record of all the past projects that were renovated by them.

6. Mr. A had not heard about RA and NN.

4.3 INTERVIEW 2

Interviewee : Ms. B

Post : Facilities manager

University : University B

Size : Large

1. Ms. B described the following methods they used for cost estimation for renovation projects:

   They use FAM in which the cost per square foot is calculated. They also consider the number of floors in a building and height of each floor for cost estimation. However, heights are usually considered only for construction projects and not renovation.

   Data is also obtained through Texas Higher Education Co-ordination Board (THECB). It gives the cost estimator a range of costs required for renovation a space. The costs differ for various facilities. The Cost estimator in University B normally takes the average of the range of costs to get the final estimate.

   RS Means is used and it gives the unit cost for all types of facilities.

2. Accuracy - The percentage error that arises due to the difference in the actual cost of renovation and the estimated cost of renovation ranges from ±5% to ±8%.

3. Speed - The fastest method for cost estimation is by getting the data from THECB as it directly provides the range of cost required and it takes around three days.
4. Ease of use - THECB, along with being the fastest method, is also very easy to use (1). The other two methods are easy to use (2).
5. Ease of getting the data required in estimating the cost –The ease of getting the required data depends on the type of project. The bigger and more complex the project is, more is the analysis required to obtain the data. For a small and simple project, the data can be obtained directly from the drawings.
6. The contingencies considered to calculate the final estimate is taken as 10%. Also, they do not use RA or NN for cost estimation.

4.4 INTERVIEW 3

Interviewee : Mr. C

Post : Facilities manager

University : University C

Size : Large

1. As said by Mr. C, they mainly use the following three types of cost estimation methods for renovation projects:

   The cost per square foot is calculated. A range for various costs is obtained by comparing the renovation project to the past projects that are similar to the one that needs to be renovated. RS Means is not used for cost estimation.

   Quantity take-off is done using the plans of the building and the cost is estimated accordingly.

Contractors are asked to quote their prices. Contractors estimated the costs based on labor and material required in the project.

2. Accuracy - The percentage error that arises due to the difference in the actual cost of renovation and the estimated cost of renovation is around ±10% if cost per square foot is considered or quantity takeoff is done, and is ±5% in case contractor's estimate is used.
3. Speed - The fastest method for cost estimation is when cost per square foot is considered; while getting the contractor's estimate is more time consuming.
4. Ease of use – Getting quotes from the contractors is very easy (1) while others are easy (2).
5. Ease of getting the data required in estimating the cost – The ease of getting required data depends on the type of project. The bigger and more complex the project is, more is the analysis required to obtain the data. For a small and simple project, the data can be obtained directly from the drawings.

   The choice of cost estimation method depends on how soon the results are required to start the renovation process. If time to estimate the cost is less, cost per square foot method is used; else, contractor's estimate is used to get a more reasonable estimate.
6. Also cost models like RA and NN are not used.

4.5 INTERVIEW 4

Interviewee : Mr. D

Post : Cost Estimator

University : University D

Size : Medium

1. University D uses the following two types of cost estimation methods for renovation projects:

   Cost per square foot is obtained from RS Means

   The contractors are asked to provide their budget estimate
2. Accuracy – The cost per square foot method gives the results with 70% to 80% accuracy while the contractor's estimate is almost 90% accurate as the contingencies are also included in the estimate.
3. Speed – It takes two to three days to calculate the cost of renovation using RS Means while the contactor's estimate generally requires a week. RS Means is used in case the time for getting the estimate is short.
4. Ease of use – Getting data from RS Means is easy (2) while getting the estimate from contractors is very easy (1).
5. Ease of getting the data required in estimating the cost – Data for the unit cost can be obtained directly from RS Means (1). Also, the contractors are very efficient and do not have any difficulty in obtaining the data required for estimating the cost of renovation (1).
6. RA and NN are not used.

4.6 INTERVIEW 5

Interviewee : Mr. E

Post : Facilities manager

University : University E

Size : Small

1. According to Mr. E, two approaches are used to estimate the project costs in University E:

   Bid from the contractors

   Estimation using unit costs of materials by the in-house team.
2. Accuracy - The bid from the contractors gives a more accurate value.
3. Speed - The contractors usually take around one week to calculate the estimated cost while the in-house team takes about three to four days for the same.
4. Ease of use - Cost estimation by the in-house team is a better method as it becomes easy to control the quality of work. As the capability of all the team members is known, there is no need to keep a check on them (1). Whereas, keeping a check on the contractors is necessary if they are asked to bid (2).
5. Ease of gathering the data required to estimate the cost - Gathering data becomes easier if the in-house team work on cost estimation. Since they are well aware of the existing conditions, they can easily gather the data (1). This also helps save time in making the specifications.
6. RA and NN are not used.

4.7 INTERVIEW 6

Interviewee : Mr. F

Post : Facilities manager

University : University F

Size : Small

1. In University F, as told by Mr. F, job order contracting is done to estimate the cost of renovation. They use cost per unit data from the RS Means.
2. Accuracy - This method gives an error of around ±10 %. However, the error might even be as much as ±40%.
3. Speed - Job order contracting takes approximately a week to calculate the cost of renovation.
4. Ease of use – Since the contractors do most of the work, this method was rated 2 for ease of use.
5. Ease of gathering the data required to estimate the cost –It is difficult to gather data (3).
6. Mr. F was familiar with RA and NN but they were not used since the projects in the campus were small and did not require the use of such models.

4.8 INTERVIEW 7

Interviewee : Ms. G

Post : Facilities manager

University : University G

Size : Small

1. As said by Ms. G from University G, for estimating the cost of renovation, an architectural firm is asked to submit a proposal. During this process they have a meeting together and take a look at the building to understand the project.
2. Accuracy - Most of the times the percentage error in the estimated cost is -20%.

3. Speed - This method takes around three weeks to get the estimated cost; however, it depends on the scale of the project too.
4. No data was obtained for ease of use of the cost model.
5. The ease of getting the data required for cost estimation depends on the age of the building and availability of the drawings. If the drawings are not available, the area is analyzed and pictures are taken to get the required information.
6. RA and NN are not used.

4.9 INTERVIEW 8

Interviewee : Mr. H

Post : Facilities manager

University : University H

Size : Small

1. Mr. H from University H, uses the cost per unit method. He usually gets the unit cost from the RS Means.
2. Accuracy – Usually the percentage error in using this method is -10%.
3. Speed – It takes one or two days to estimate the cost.
4. Ease of use – This method is very easy to use and any one in the department can estimate the cost using RS Means (1).
5. Ease of gathering the data - The as-built drawings are more or less accurate and they can directly get the area and multiply it with the unit cost (1).
6. RA and NN are not used.

4.10 INTERVIEW 9

Interviewee : Mr. I

Post : Facilities manager

University : University I

Size : Small

1. Mr. I from University I, uses cost per unit method and gets the unit cost from RS Means.
2. Accuracy – The percentage error obtained by using this method is ±10%.
3. Speed – The cost estimator is well-versed with the building spaces and hence it takes less than a day to estimate the cost of renovation.
4. Ease of use – This method is very easy (1) to use as the costs can be taken directly from RS Means.
5. Ease of gathering the data – Most of the times it is easy (2) to obtain the data from the drawings. However, in case of some discrepancies in the as-built drawings, the area to be renovated needs to be surveyed.
6. RA and NN are not used.

4.11 INTERVIEW 10

Interviewee : Ms. J

Post : Facilities manager

University : University J

Size : Medium

1. Ms. J from University J said that they use 2 methods:

FAM

CBR

2. Accuracy – The percentage error usually obtained during cost estimation was not revealed.
3. Speed – Both the methods, take around one to two weeks to calculate the cost of renovation.
4. Ease of use – As compared to CBR, FAM is much easier to use. The updated costs are available in the RS Means (1). If CBR is used, the cost needs to be updated according to the current market conditions (2).
5. No data was obtained for ease of getting data.
6. RA and NN are not used.

5. DISCUSSION

5.1 INTRODUCTION

FAM, RS Means, QTO and THECB use cost per unit for cost estimation. Hence they all are assumed to be categorized under FAM. Per the interviews, FAM was the most widely used cost model. Figure 6 shows that six facilities managers outsourced the work to either contractors or architectural firms, but did not use any of the cost models. Two facilities managers used case-based-reasoning. Out of the 10 facilities managers, only one knew about regression analysis and neural networks. The other had not heard of those cost models.

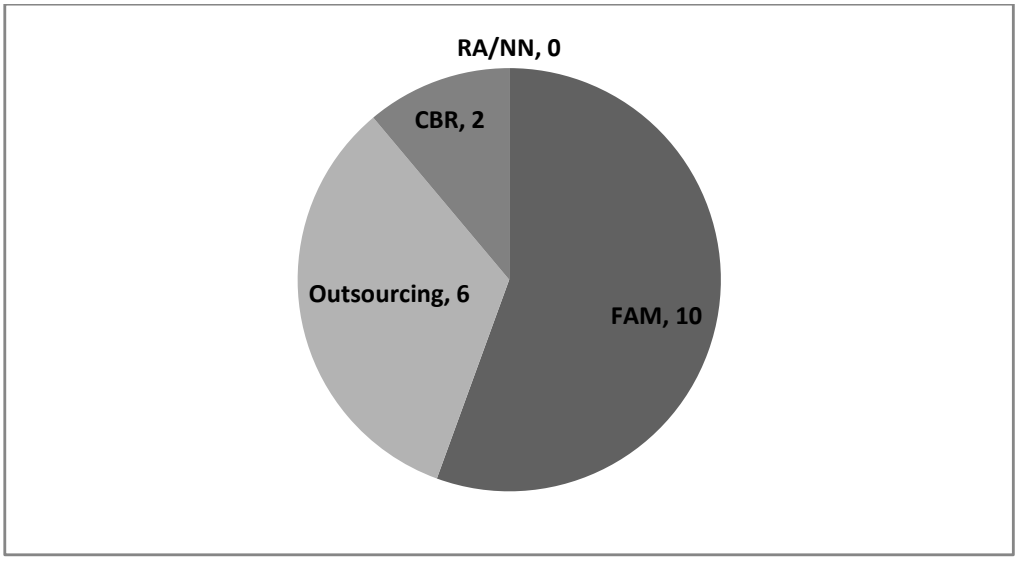

Fig. 6. Number of Facilities Managers Using a Cost Model

5.2 ACCURACY

Below are bar charts that compare the cost models used by each interviewee on the basis of their accuracy. Since a few interviewees had information of more than one cost model, thus only those interviews are taken into consideration for intra-comparison of the cost models.

As per interview 3, outsourcing the job of cost estimation gives a lower percentage error as compared to FAM (refer figure 7).

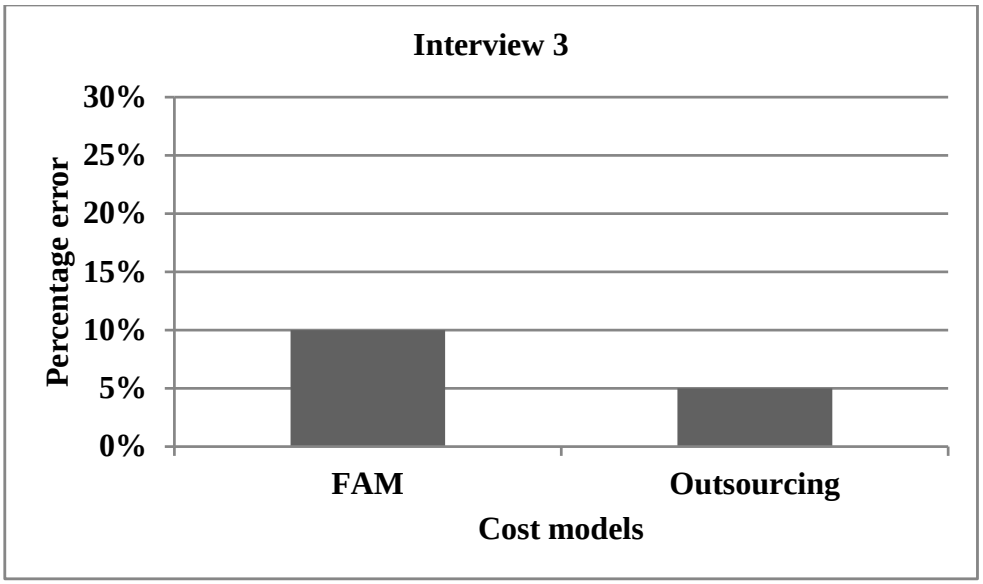

Fig. 7. Percentage Errors as per Interview 3

As per interview 4, outsourcing the job of cost estimation gave a lower percentage error than FAM (refer figure 8).

The interviewees who used more than 1 cost model did not find FAM as accurate as outsourcing the job.

Figures 9 and 10 show summary of all the findings obtained for the variable accuracy. In all, eight facilities managers gave the percentage errors in the estimated cost of renovation when they used FAM. Figure 9 gives the graphical representation of the same.

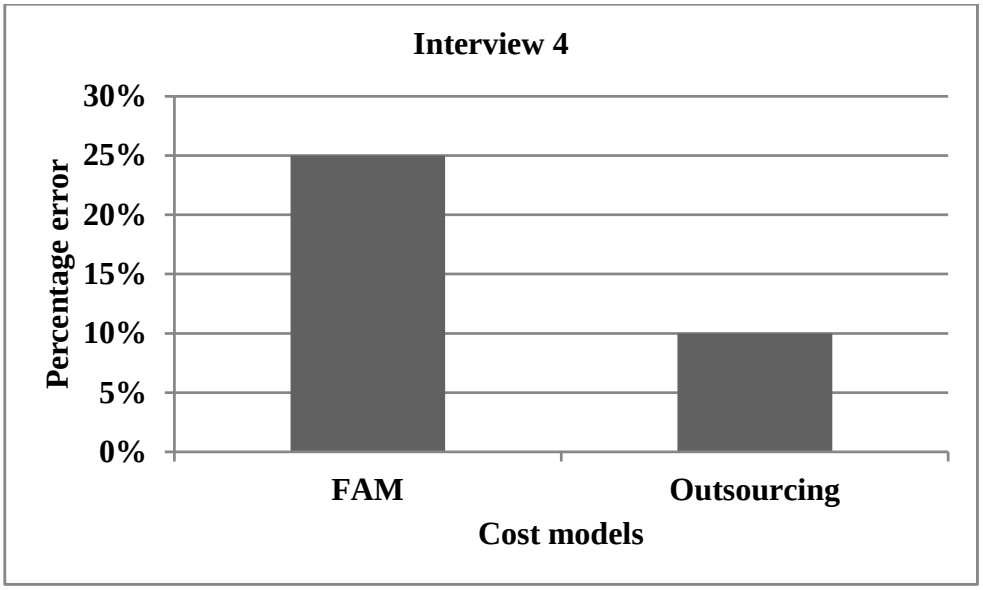

Fig. 8. Percentage Errors as per Interview 4

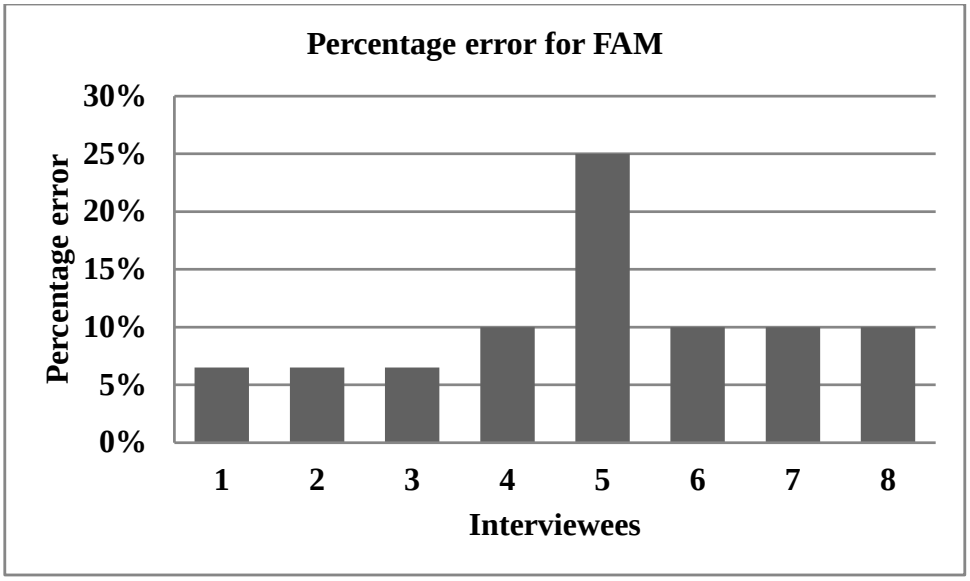

Fig. 9. Percentage Errors in the Estimated Cost using FAM

Four facilities managers gave the percentage errors in the estimated cost of renovation when they outsourced the job to either contractors or architects and engineers. Figure 10 shows the bar chart that represents the data obtained.

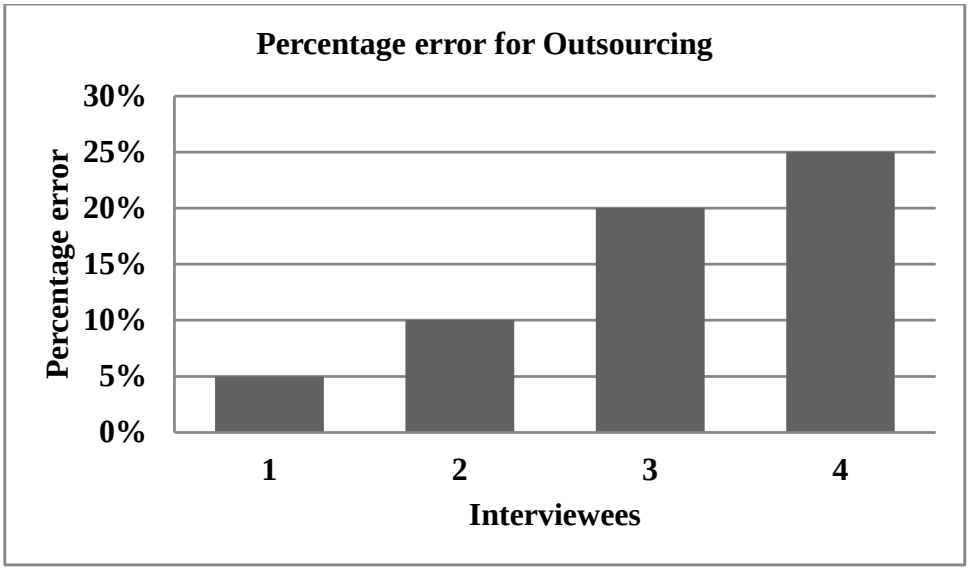

Fig. 10. Percentage Errors in the Estimated Cost using Outsourcing

Table 2 shows the list of percentage errors obtained for FAM and outsourcing.

Table 2. Summary of Percentage Errors in the Estimated Cost

		FAM	CBR	Outsourcing
Percentage error		6.50%	-	5%
		6.50%	-	10%
		6.50%	-	20%
		10%	-	25%
		25%	-	
		10%	-	
		10%	-	
		10%	-	
	Average	10.56%	-	15.00%
	Mode	10%	-	N/A

No data was obtained for CBR model. Although outsourcing is not a cost model as per literature search, it is considered in this research due to the interviewees' responses. The average and mode of the error for FAM and outsourcing were calculated.

Since all the values obtained for outsourcing were different, a mode could not be obtained. Thus the averages of both can be compared. Since the average error of FAM is less, it can be said that FAM is more accurate.

Figure 11 shows that most of the data collected for percentage errors in FAM lie within the range of 5%-10% while that in outsourcing the percentage errors lie in the range of 10%-20%.the average maximum error in both the case can however go as high as 25%.

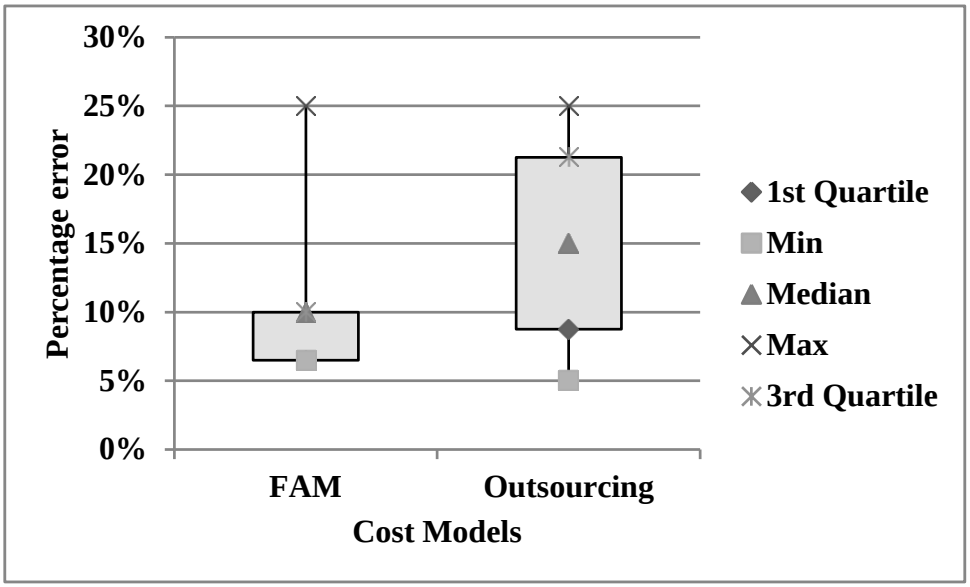

Fig. 11. Percentage Errors for FAM and Outsourcing

Thus the overall comparison shows that FAM is more accurate, whereas for the facilities managers who used both FAM and outsourcing found the latter to be more accurate.

5.3 SPEED

Below are the bar charts that compare the cost models used by each interviewee on the basis of the time taken to estimate the cost.Per interview 1, FAM takes around two days to estimate the cost of renovation as compared to outsourcing that takes almost a week to do the same (refer figure 12).

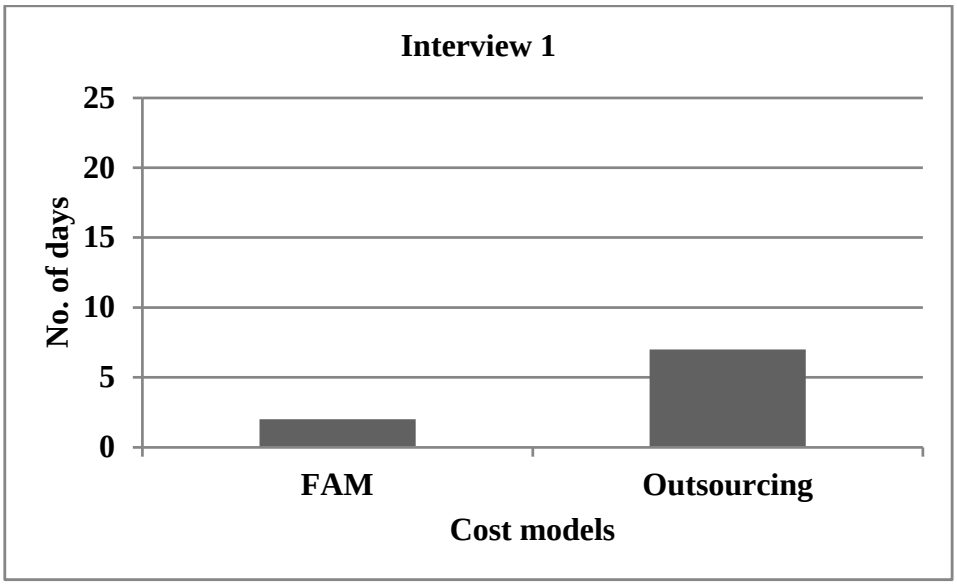

Fig. 12. Speed of Cost Models for Calculating the Renovation Cost per Interview 1

Per interview 4, FAM takes two to three days (average of two and a half days) to estimate the cost of renovation as compared to outsourcing that takes almost a week to do the same (refer figure 13).

Per interview 10, both FAM and CBR take almost the seven to fourteen days (average of 10.5 days) to estimate the cost of renovation (refer figure 14).

Thus, outsourcing takes the maximum amount of time while FAM and CBR take comparatively less time.

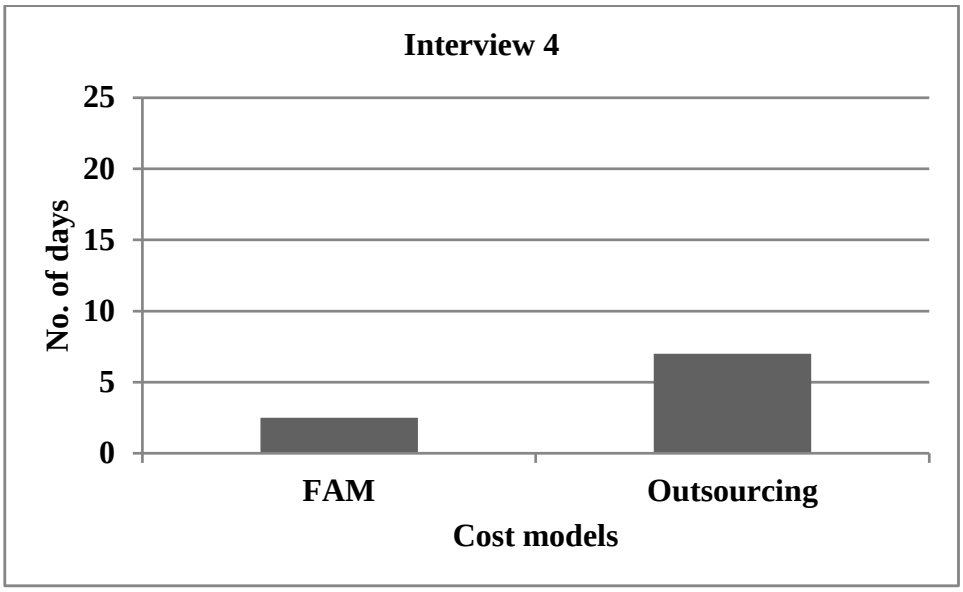

Fig. 13. Speed of Cost Models for Calculating the Renovation Cost per Interview 4

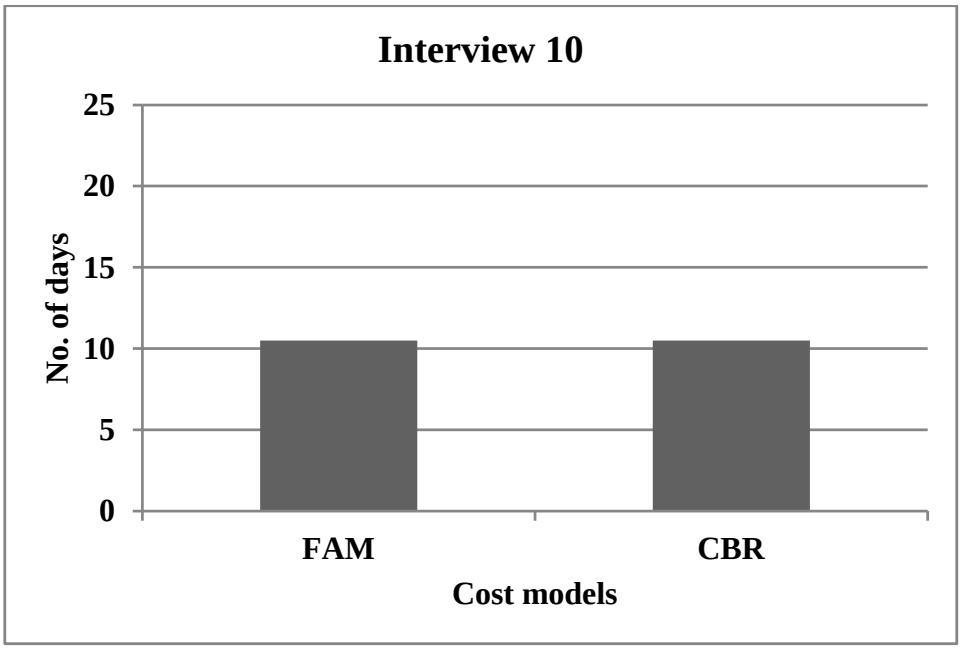

Fig. 14. Speed of Cost Models for Calculating the Renovation Cost per Interview 10

Figure 15and 16 give the summary of all the findings obtained for the variable speed.

Six facilities managers gave the time taken by FAM to calculate the cost of renovation. Five of them took less than four days to calculate the cost. However, according to one interviewee, it took more than 10 days to calculate the cost. Figure 15 gives a graphical representation of the same.

Figure 16 shows that out of five facilities manager, four take around a week to calculate the cost of renovation. One facilities manager said that it took around one to three weeks for cost estimation.

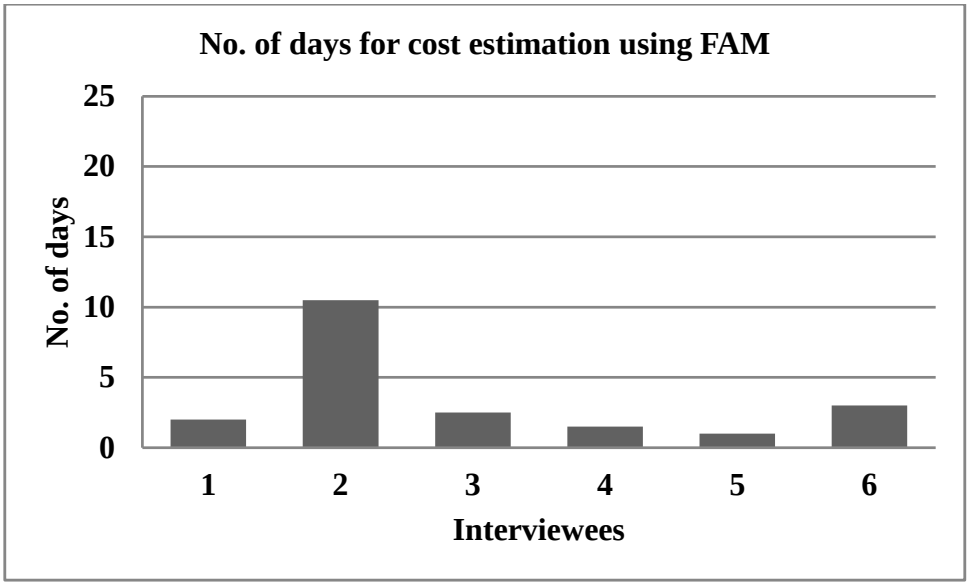

Fig. 15. Speed of FAM for Calculating the Renovation Cost

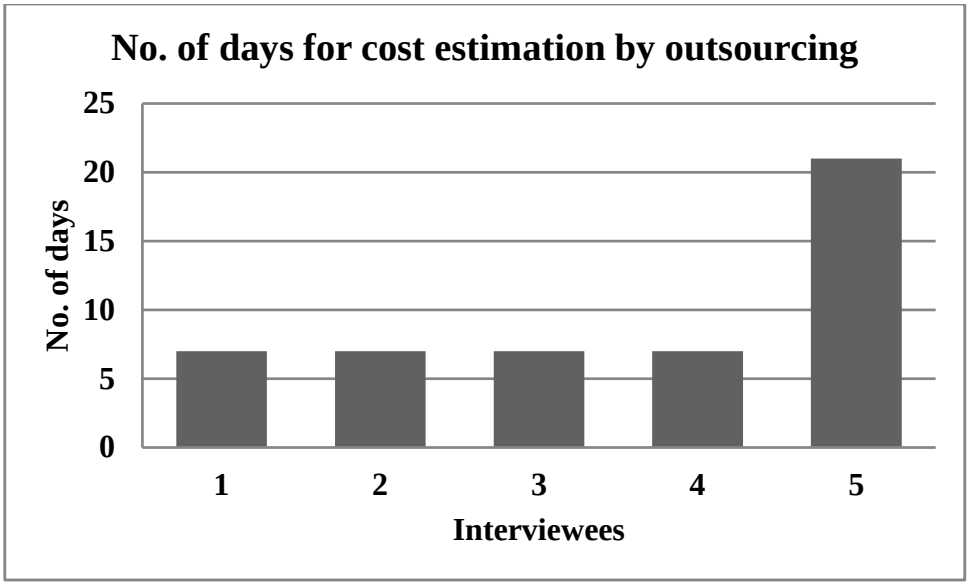

Fig. 16. Speed of Outsourcing for Calculating the Renovation Cost

Table 3 gives the list of all the responses given for the speed of the cost models.

Table 3. Summary of the Speed of Cost Models in Calculating the Renovation Cost

		FAM	CBR	Outsourcing
Speed		2	10.5	7
in days		10.5	-	7
		2.5	-	7
		1.5	-	7
		1	-	21
		3	-	
	Average	3.42	-	9.8
	Mode	N/A	-	7

Since all the responses were different for FAM, its mode could not be calculated. On an average, three and a half days are required to calculate the cost of renovation using FAM while nearly ten days are required in the job is outsourced. This indicated that FAM gives results faster than outsourcing.

Figure 17 shows that most of the data collected for the speed of FAM lies between two to three days. Outsourcing takes around one week, however it could take around three weeks also depending on the project.

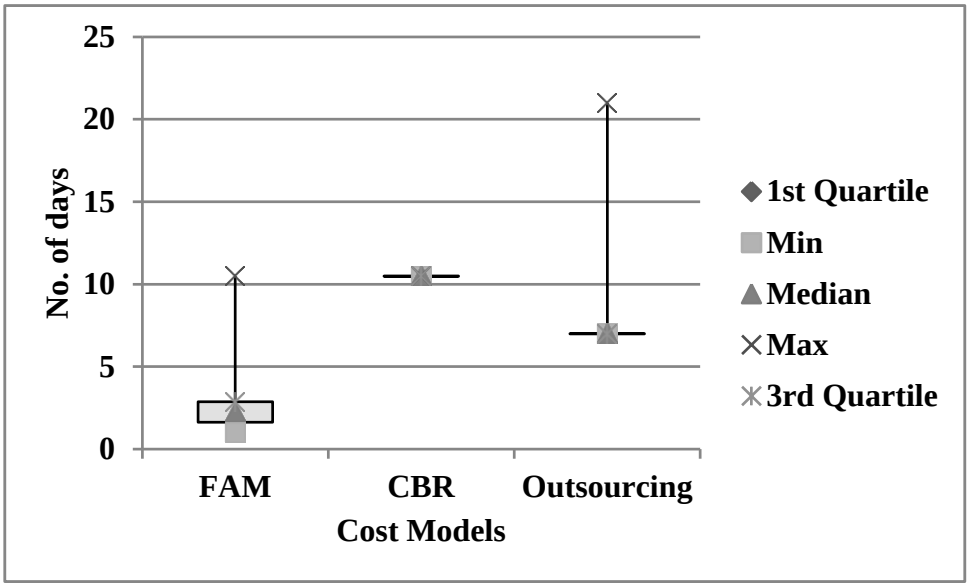

Fig. 17. Speed of FAM, CBR and Outsourcing

5.4 EASE OF USE

Below are the bar charts that compare the cost models used by each interviewee on the basis of their ease of use whileestimating the cost of renovation.Per interview 1, FAM is the easiest to use as compared to outsourcing and CBR (refer figure 18).

Per interview 3, FAM was rated as 2 i.e. easy to use; however outsourcing the job was the easiest way of cost estimation (refer figure 19).

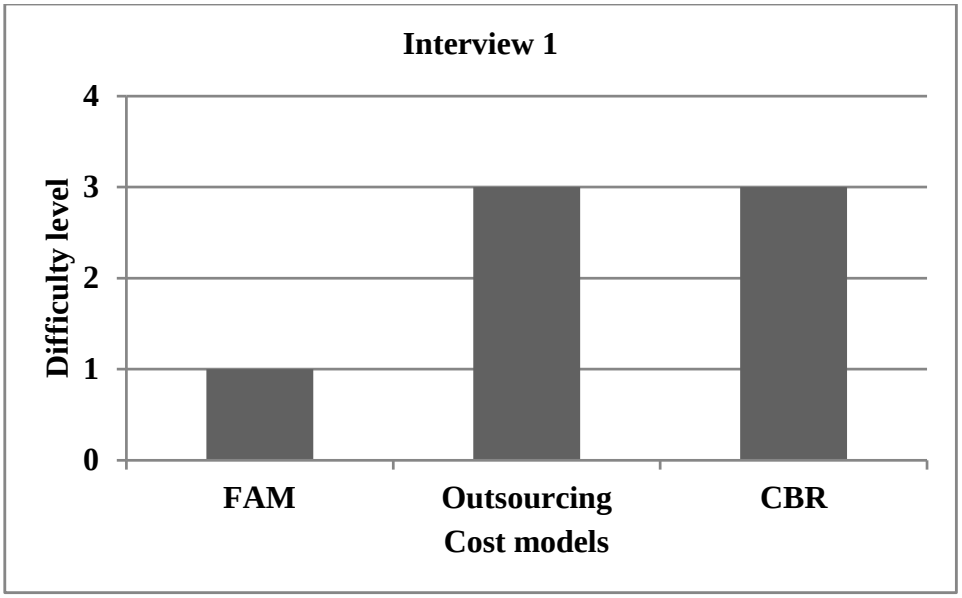

Fig. 18. Ratings for Ease of Use of Cost Models per Interview 1

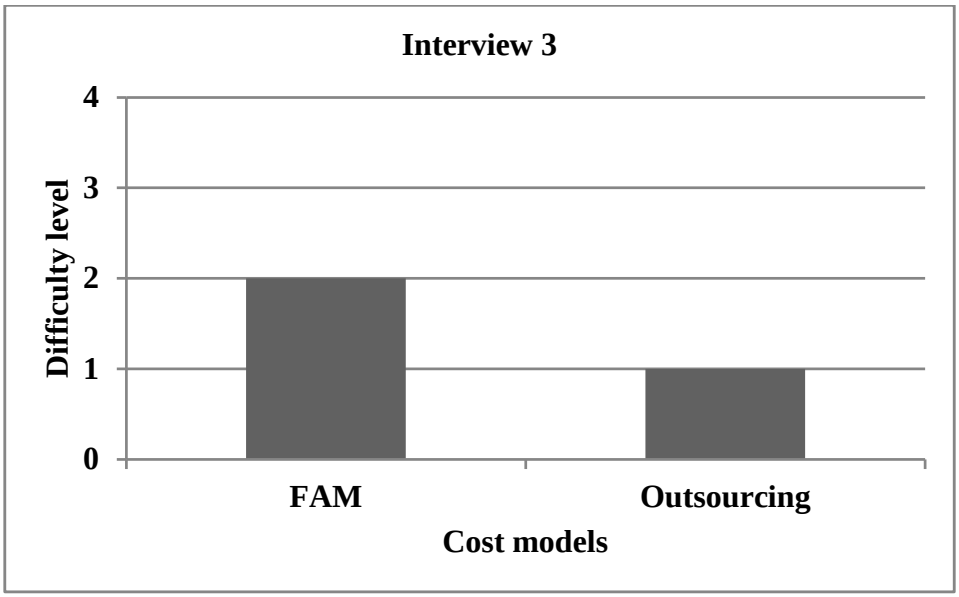

Fig. 19. Ratings for Ease of Use of Cost Models per Interview 3

Per interview 4, though outsourcing was easy, FAM was the easiest to use (refer figure 20).

Per interview 10, CBR was easy to use while FAM was very easy to use (refer figure 21).

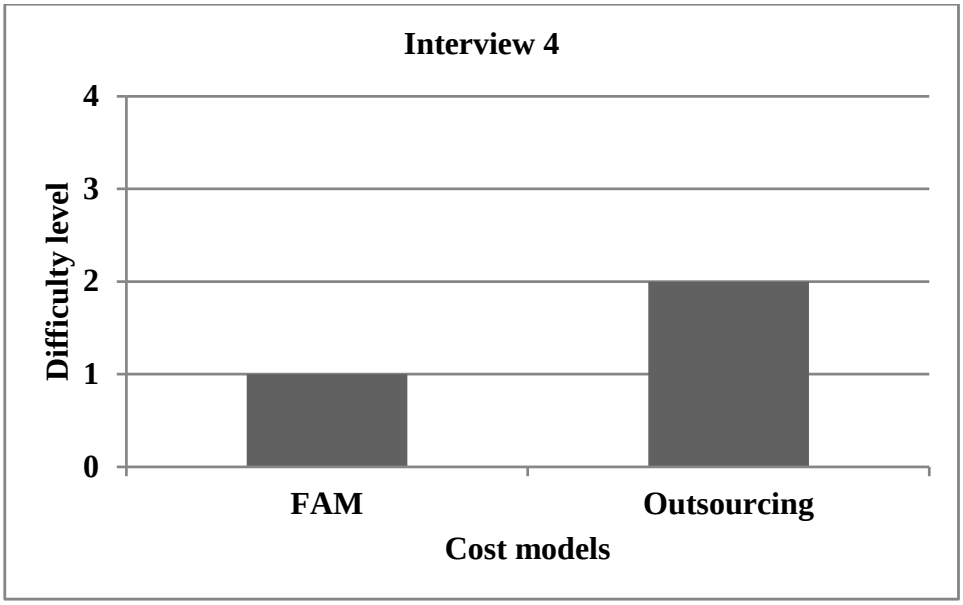

Fig. 20. Ratings for Ease of Use of Cost Models per Interview 4

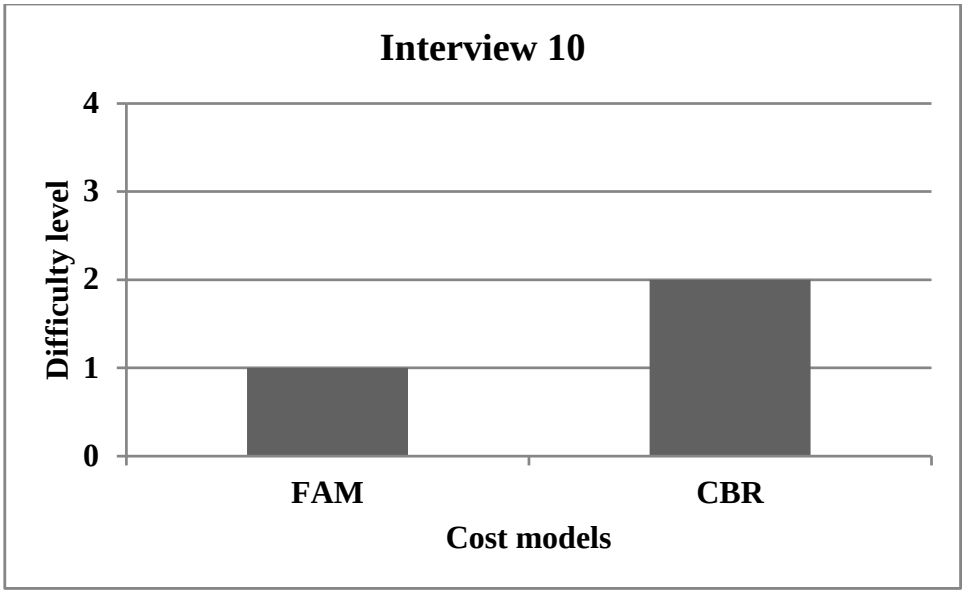

Fig. 21. Ratings for Ease of Use of Cost Models per Interview 10

Below is the summary of all the findings obtained for the variable ease of use. Figure 22 shows the ratings given by the interviewees for the ease of use of FAM. Out of ten facilities managers seven rated it as very easy to use.

Figure 23 shows the graphical representation of the ratings obtained for ease of use of outsourcing. Most of them rated it as 2 i.e. easy.

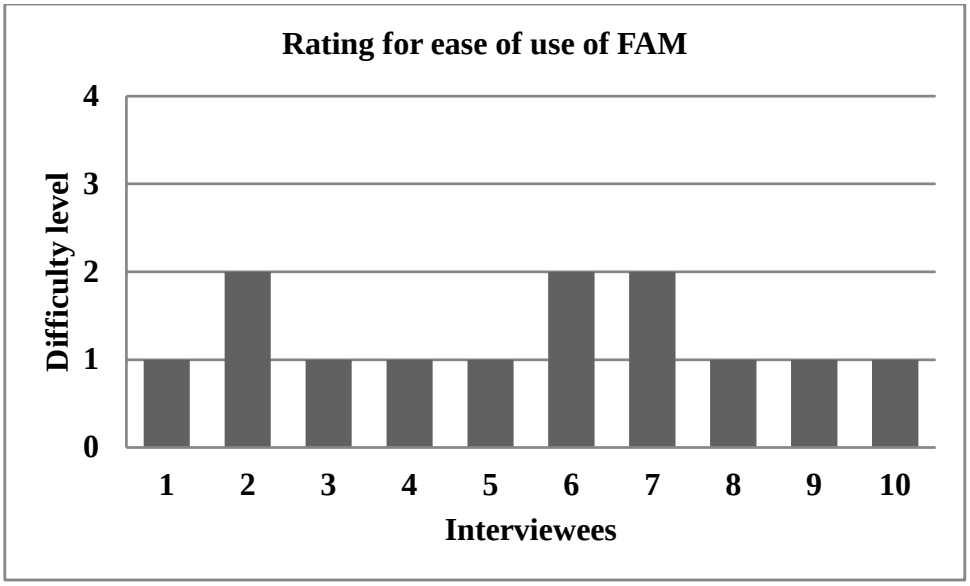

Fig. 22. Ratings for Ease of Use of FAM

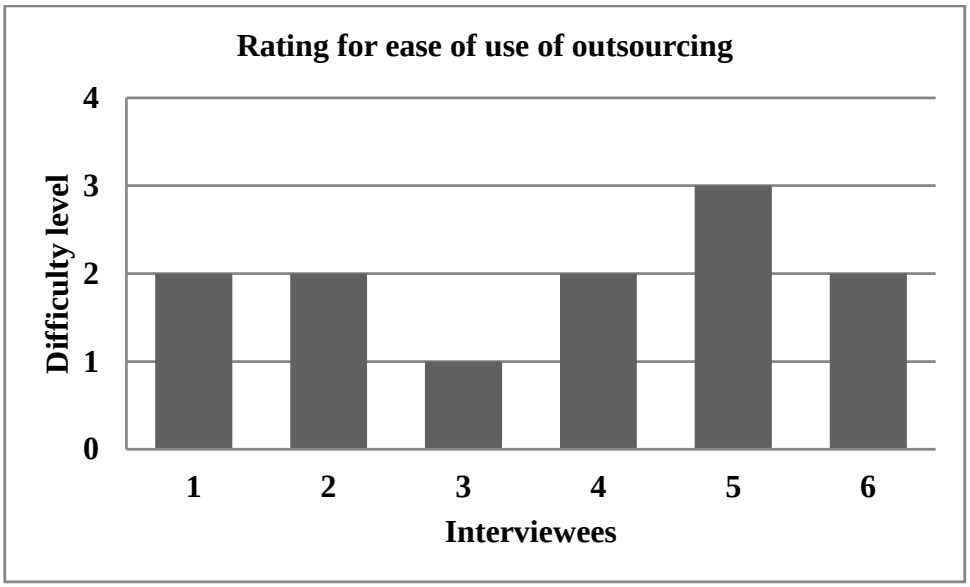

Fig. 23. Ratings for Ease of Use of Outsourcing

Table 4 gives the list of all the ratings obtained for FAM, CBR and outsourcing.

Table 4. Summary of the Ratings for Ease of Use of the Cost Models

		FAM	CBR	Outsourcing
Ease of use		1	3	2
		2	2	2
		1	-	1
		1	-	2
		1	-	3
		2	-	2
		2	-	-
		1	-	-
		1	-	-
		1	-	-
	Average	1.3	2.5	2
	Mode	1	N/A	2

The averages of the ratings of each cost model were calculated. The average rating of FAM is the lowest while that of CBR is highest. Also, the model of the ratings for FAM is 1 while that for outsourcing is 2. Thus, FAM is the easiest to use, followed by CBR and outsourcing. Outsourcing the job to contractors and architectural firms got a range of ratings from very easy to difficult. This could be due the fact that the efficiency and rapport with each firm might differ.

Figure 24 shows that FAM is easier to use than CBR. Outsourcing on the other hand got a range of ratings.

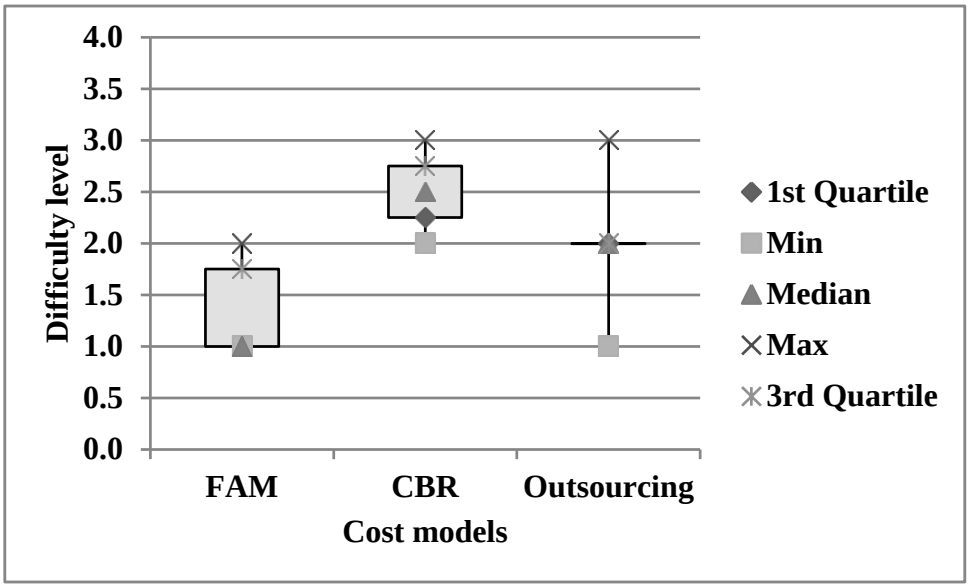

Fig. 24. Ease of Use of FAM, CBR and Outsourcing

5.5 EASE OF GATHERING DATA

Below are the bar charts that compare the cost models used by each interviewee on the basis of ease of data collection required to estimate the cost of renovation.Per interviews 1 and 4, FAM, outsourcing and CBR takes almost the same amount of effort in gathering the data. It is easy to gather the data in all the three cases. Figures 25 and 26 give the graphical representation for the same.

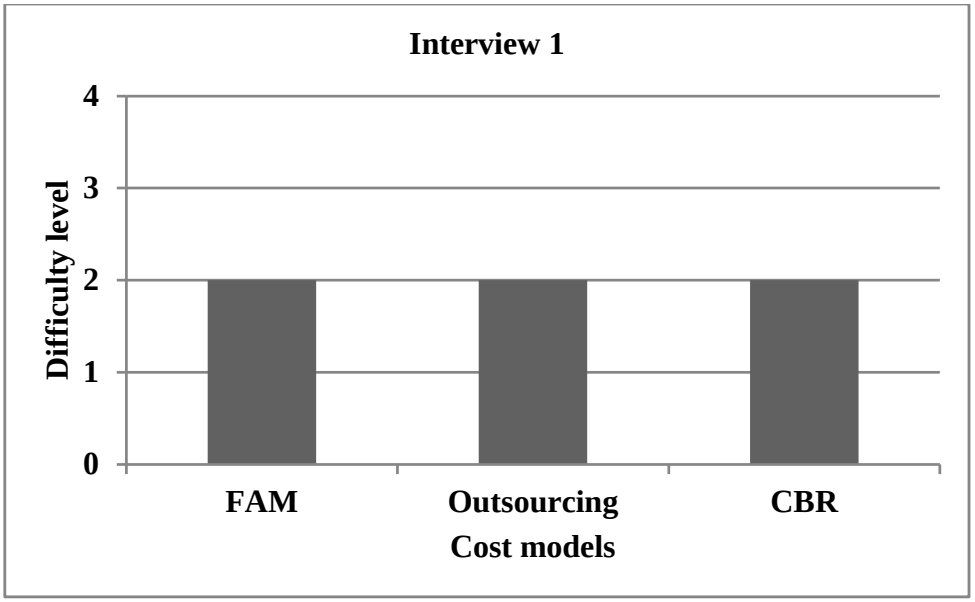

Fig. 25. Ratings for Ease of Data Collection for the Cost Models per Interview 1

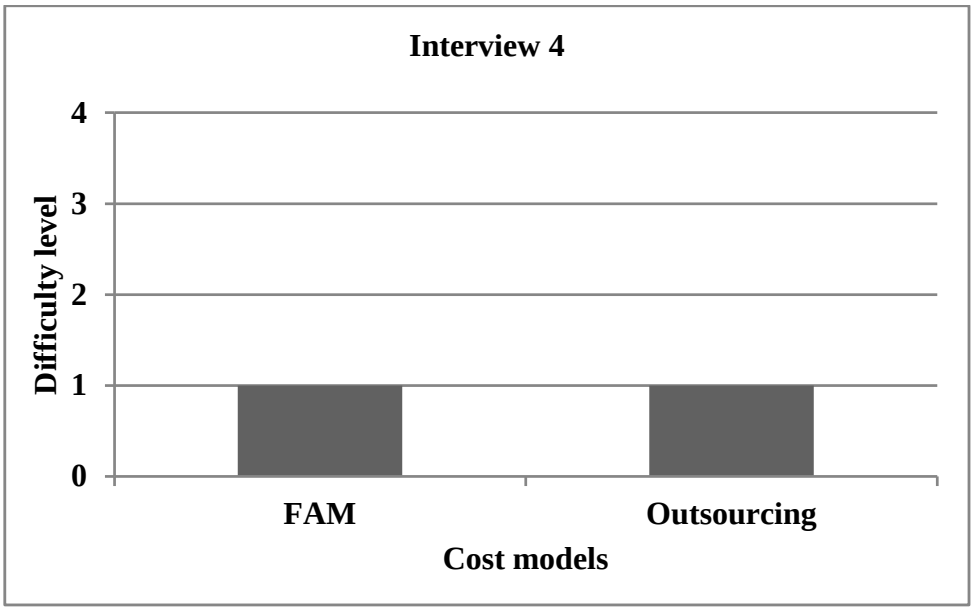

Fig. 26. Ratings for Ease of Data Collection for the Cost Models per Interview 4

Per interview 10, it is easier to gather data when using FAM as compared to using CBR (refer figure 27).

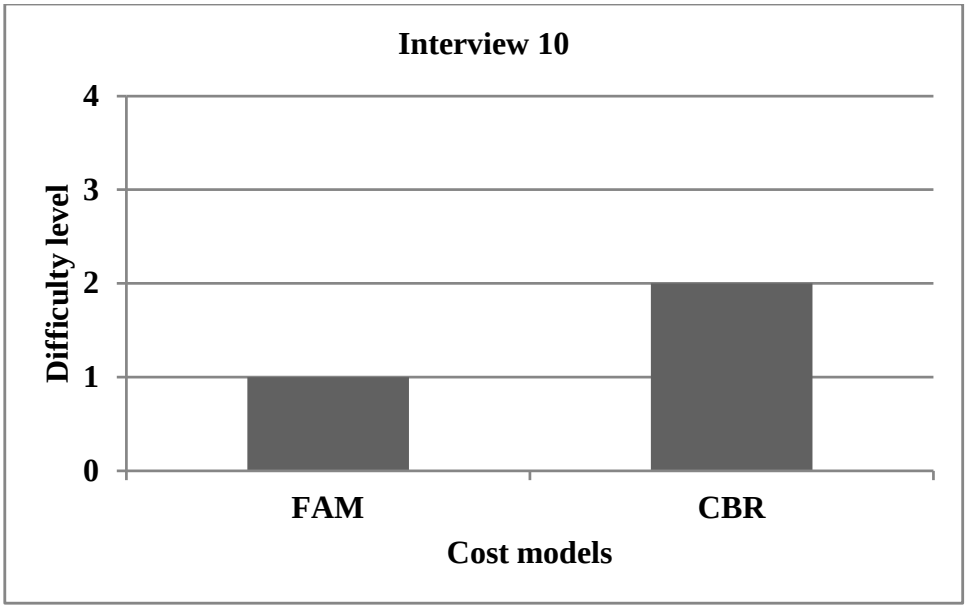

Fig. 27. Ratings for Ease of Data Collection for the Cost Models per Interview 10

Below is the summary of all the findings obtained for the variable ease of gathering the data.

Out of four responses for ease of gathering data in FAM, two said it was very easy (1) while the other two said it was easy (2) (refer figure 28).

Figure 29 shows the ratings obtained for ease of gathering data using outsourcing. This category got varied responses.

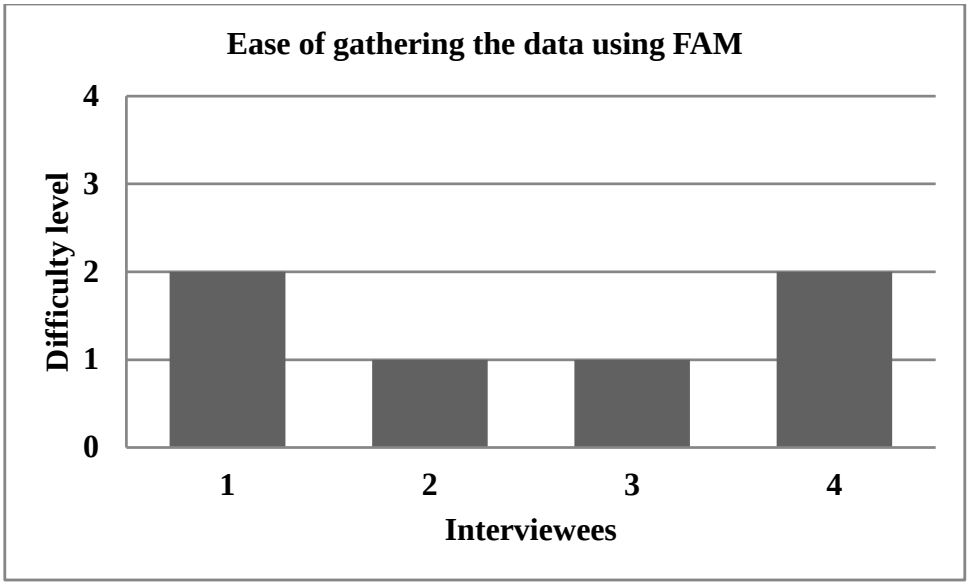

Fig. 28. Ratings for Ease of Data Collection when using FAM

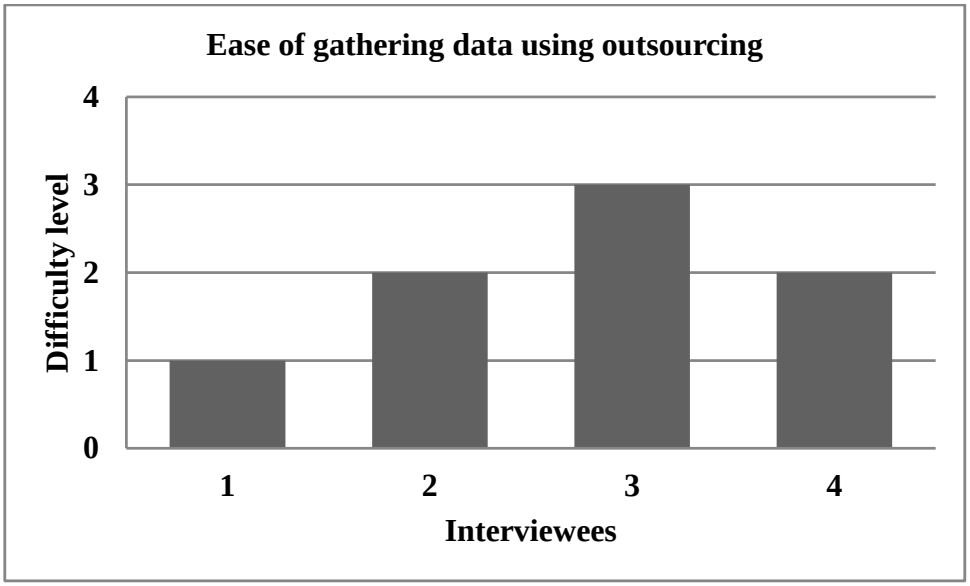

Fig. 29. Ratings for Ease of Data Collection when using Outsourcing

Table 5 gives the list of ratings obtained for ease of gathering data for FAM, CBR and outsourcing.

Table 5. Summary of the Ratings for Ease of Data Collection for the Cost Models

		FAM	CBR	Outsourcing
Ease of gathering the data		2	2	1
		1	-	2
		1	-	3
		2	-	2
	Average	1.5	2	2
	Mode	2	N/A	2

The average rating for FAM is lowest. However the modes for all are the same. Thus, FAM, outsourcing and CBR take almost the same amount of effort in gathering the data. Also outsourcing is rated as very easy, easy as well as difficult. This range could be due to the complexity of design or availability of data.

Figure 30 shows that FAM and CBR are both easy to use. CBR, however, got just one rating. The difficulty level of outsourcing ranges from “very easy” to “difficult”.

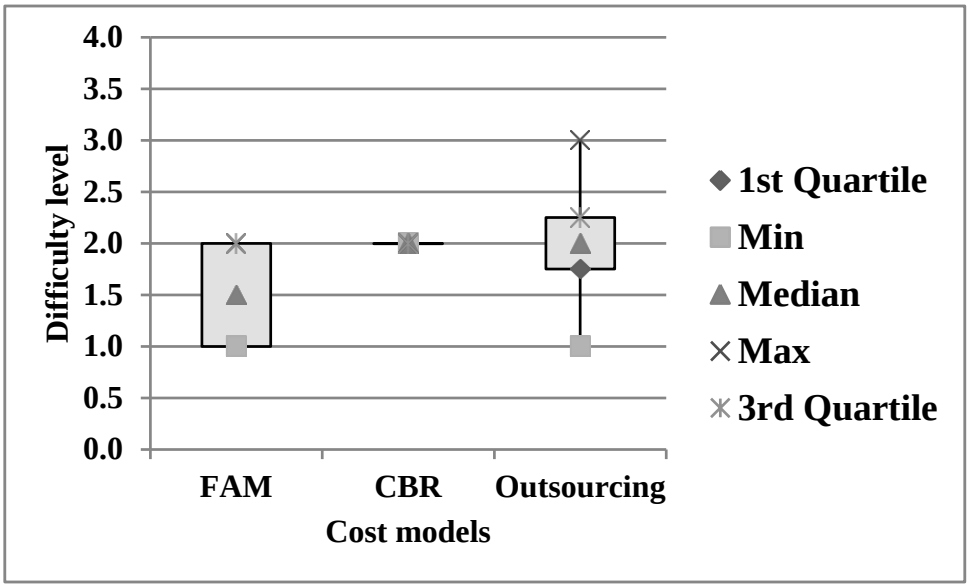

Fig. 30. Ease of Data Collection for FAM, CBR and Outsourcing

6. CONCLUSION

Since all the universities in the research are located in Texas, the climatic conditions and the price fluctuations in the market are considered to be constant. The facilities managers who were interviewed were asked to give information on the projects they completed in the past five years. The area of renovation was considered to be around 5000 sq. feet. Table 6 shows the results that were obtained from the interviews:

Table 6. Results Obtained for Each Variable of the Cost Models

		FAM	CBR	Outsourcing
Percentage error	Average	10.56%	-	15.00%
	Mode	10%	-	N/A
Speed	Average	3.42	-	9.8
	Mode	N/A	-	7
Ease of use	Average	1.3	2.5	2
	Mode	1	N/A	2
Ease of data collection	Average	1.5	2	2
	Mode	2	N/A	2

Table 6 shows that FAM is the most accurate, less time consuming, easy to use as well as convenient for data collection. Literature suggests that the newer models like regression analysis and neural networks give more accurate and realistic results. However these new models take more time in calculating the cost as it requires a trial and error process. For example, many different values need to be substituted in the RA equations to get the most accurate equation. Out of the ten interviewees, only one was

aware of these new models but did not use them as they would be helpful for very large projects and they would need expertise. Thus such models should be simplified to not only give accurate results in less time but also be easy to use. CBR, though not as widely used as FAM, is known to facilities managers. However, if a new type of project needs to be renovated, and the data for a similar project is not available with the facilities manager, it becomes difficult to calculate the estimated cost. This issue can be resolved by creating a common forum where data for all types of project could be made available for the facilities managers.

The above results will help future researchers to modify the new and accurate models or develop a more competent model to suit the needs of the user. Also, FAM is the most widely accepted cost model. In this research many different methods were considered under FAM. The future researchers could explore these methods to identify which method is the most efficient and gives accurate results. This could give a base for modifying the cost models that are currently in demand. It would also be interesting to test if the perception of increased accuracy from outsourcing could be validated by reality. Building Information Modeling (BIM) is one of the upcoming fields in the construction industry. Practitioners have started using 5D BIM to estimate the cost of a structure along with making its 3D model and working on its construction schedule. Since 5D modeling will be soon used extensively, it would be interesting to learn about the role of BIM as a cost model.

REFERENCES

Carbone, R., and Armstrong, J. S. (1982). "Evaluation of extrapolative forecasting methods: Results of a survey of academicians and practitioners." *Journal of Forecasting,* 1(2), 215-217.

Cheung, F. K. T., and Skitmore, M. (2006). "Application of cross validation techniques for modeling construction costs during the very early design stage." *Building and Environment,* 41(12), 1973-1990.

Edum-Fotwe, F. T., Eqbu, C., and Gibb, A.G.F. (2003). "Designing facilities management needs into infrastructure projects: Case from a major hospital." *Journal of Performance of Constructed Facilities*, 17(1), 43-50.

Kim, G., An , S., and Kang, I. (2004). "Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning." *Building and Environment,* 39(10), 1235-1242.

Hwang, S. (2009). "Dynamic regression models for prediction of construction costs." *Journal of Construction Engineering and Management*, 135(5), 360-367.

Poremba, A. (1998). "Early cost intelligence for renovation projects." *Proceedings of the 1998 42nd Annual Meeting of AACE International,* AACE International, Cincinnati, OH, PCS.03.1 – PCS.03.7.

Skitmore, M., Stradling, S.G., Tuohy, A., and Makwezalamba, H. (1990). *The accuracy of construction price forecasts: A study of quantity surveyors' performance in early stage estimating*, University of Salford, Manchester.

Skitmore, M., and Thomas, S. (2003). "Forecast models for actual construction time and cost." *Building and Environment*, 38 (8), 1075-1083.

Sonmez, R. (2004). "Conceptual cost estimation of building projects with regression analysis and neural networks." *Canadian Journal of Civil Engineering*, 31(4), 677-683.

Wang, H. Chiou, C., and Juan, Y. (2008). "Decision support model based on case-based reasoning approach for estimating the restoration budget of historical buildings." *Expert Systems with Applications*, 35(4), 1601-1610.

Witt, S., and Witt, C. (1992). *Modeling and forecasting demand in tourism.* Academic Press Ltd., London.

Yokum, J. T., and Armstrong, J. S. (1995). "Beyond accuracy: Comparison of criteria used to select forecasting methods." *International Journal of Forecasting,* 11(4), 591-597.

APPENDIX A

IRB APPROVAL

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex
College Station, TX 77843-1186
750 Agronomy Road, #3500

979.458.1467
FAX 979.862.3176
http://researchcompliance.tamu.edu

Human Subjects Protection Program — Institutional Review Board

DATE: 01-Jun-2010

MEMORANDUM

TO: FAQUIH, YAQUTA
77843-3578

FROM: Office of Research Compliance
Institutional Review Board

SUBJECT: Amendment

Protocol Number:	2010-0244
Title:	Comparative Analysis of the Cost Models Used for Estimating Renovation Costs of Hospital Buildings
Review Category:	Expedited
Approval Period:	01-Jun-2010 **To** 18-Apr-2011

Approval determination was based on the following Code of Federal Regulations:

45 CFR 46.110(b)(2) - Minor changes in previously approved research during the period of (one year or less) for which approval is authorized.

Provisions: Change in persons interviewed and deletion of survey form.

This research project has been approved for one (1) year. As principal investigator, you assume the following responsibilities

1. **Continuing Review:** The protocol must be renewed each year in order to continue with the research project. A Continuing Review along with required documents must be submitted 30 days before the end of the approval period. Failure to do so may result in processing delays and/or non-renewal.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB Office.
3. **Adverse Events:** Adverse events must be reported to the IRB Office immediately.
4. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB Office for review. The Amendment must be approved by the IRB before being implemented.
5. **Informed Consent:** Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project.

This electronic document provides notification of the review results by the Institutional Review Board.

APPENDIX B

IRB AMENDMENT APPROVAL

TEXAS A&M UNIVERSITY
DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex 979.458.1467
College Station, TX 77843-1186 FAX 979.862.3176
750 Agronomy Road, #3500 http://researchcompliance.tamu.edu

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DATE: 01-Jun-2010

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77843-3578

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1. **Continuing Review:** The protocol must be renewed each year in order to continue with the research project. A Continuing Review along with required documents must be submitted 30 days before the end of the approval period. Failure to do so may result in processing delays and/or non-renewal.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB Office.
3. **Adverse Events:** Adverse events must be reported to the IRB Office immediately.
4. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB Office for review. The Amendment must be approved by the IRB before being implemented.
5. **Informed Consent:** Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project.

This electronic document provides notification of the review results by the Institutional Review Board.

VITA

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