

# Sensitivity of the ICTAD Price Fluctuation Formula Procedure for the True Material Price Fluctuations in Construction Industry

S. A. Y. B. Jayasinghe\*, C. S. Alahakoon, L. S. S. Wijewardena

Department of Civil Engineering, The Open University of Sri Lanka, Nawala, Nugegoda,  
Sri Lanka.

\*Corresponding Author - email: ybhatiya@gmail.com, Tele: +94714425013

---

**Abstract**—Some clients and contractors of long term construction projects experience that the Price Adjustment (PA) technique for price fluctuations introduced by the Institute of Construction Training and Development (ICTAD) known as the “ICTAD formula method for adjustment to contract price due to fluctuation in prices” has some uncertainty when used to calculate the contract price fluctuations. This issue arises basically due to the non-conformity of the price indices (PI) and uncertainty of the fundamental assumptions on which the ICTAD formula derivation is based on. Therefore, this paper would study on the degree of sensitivity of the ICTAD price fluctuation formula method with the true material price fluctuation. The analyses pointed that the ICTAD price adjustment seriously depended on valuation assessed, input percentage, PI and fixed coefficient (FC) - 0.966. The latter directly depends on the cost adjustment factor (CAF) and rest adjustment factor (RAF). The combined effect of all these factors are statistically analyzed using the gathered data to propose a modified FC which can address the shortcomings of the current ICTAD formula FC - 0.966. At the end of this study, a modified FC of 0.757 which allows CAF up to 51.2% and RAF up to 12.6% is proposed using the linear regression and the weighted average basis, which can be used in the ICTAD formula. This coefficient models the true price fluctuation more closely than when calculated using the current 0.966. **Copyright © 2012 The Open University of Sri Lanka-All rights reserved.**

**Keywords:** Cost Adjustment Factor, Fixed Coefficient, ICTAD Price Adjustment, Input Percentage, Rest Adjustment Factor

---

## NOMENCLATURE

$F$ - price adjustment for the period (Rs.)	<i>Subscripts</i>
$V$ - valuation of work done during the period concerned (Rs.)	$x$ - input X
$V_{na}$ - value of non-adjustable elements (Rs.)	$c$ - current
$P$ - percentage cost contribution (%)	$b$ - base
$I$ - index published by ICTAD	$C$ - conventional
$X$ - fixed coefficient	$F$ - formula
$K$ - cost adjustment factor	
$R$ - rest adjustment factor	

## **1 INTRODUCTION**

Fluctuations of material prices present a range of challenges and consequences for the construction industry such as high contractor bids that include a cushion that can render the bids uncompetitive. Consequences also include dramatic contract losses and defaults, severely impacted and delayed projects and litigation resulting from efforts to mitigate, shift or recover unanticipated losses.

Application of the price fluctuations to the contract amount largely depends on the category of contract that the construction project follows. Therefore, there is a necessity of a simple mechanism to compute the price fluctuation as closely as possible to the true fluctuation so that the client as well as the contractor is both satisfied. The Institute for Construction Training and Development (ICTAD), which is the regulatory authority for the construction works related activities in Sri Lanka, has developed a general formula for adjustments to contract price due to fluctuation in prices.

This formula should model the actual price fluctuations as closely as possible and at the same time should be simple enough to be used repetitively and frequently since calculation of actual price fluctuations is a tedious task. Also, it should be applicable to any type of construction work, be it building construction, road works, irrigation works, heavy construction etc. ICTAD price fluctuation formula introduced for this purpose has been in use for quite some time but very little has been done to study the sensitivity of the formula to actual price fluctuations.

Since price fluctuations are unavoidable in long term construction projects, ICTAD price fluctuation clauses are generally included under contract conditions and a substantial amount of money is paid to the contractor to compensate for price fluctuations due to the general inflationary nature of prices. This necessitates a thorough study of sensitivity of the ICTAD formula and based on the current highly competitive nature of the construction industry any modifications required needs to be done not to disadvantage both the client and the contractor.

### **1.1 Aim and Objectives**

The aim of this study is to evaluate on the sensitivity of the ICTAD price fluctuation formula method for the successful construction projects. Three objectives were set to achieve this aim namely; to find the relationship between ICTAD price adjustments & true price adjustments through the data analysis, to estimate the accuracy of the ICTAD formula method for the Price Adjustments (PAs) through the sensitivity analysis and to propose a modification to increase the accuracy of ICTAD formula through the statistical analysis.

### **1.2 Focus and Purpose of the Study**

This paper will critically discuss the nexus between currently used price fluctuation computation method formulated by ICTAD and the true price fluctuation determined by the first principles i.e. the conventional method. Also, this study seeks to identify some critical causes leading to the uncertainty of the PAs due to the application of general ICTAD fluctuation formula. Required data will be collected basically from the selected

construction projects, private sector organizations, experienced persons in civil engineering field etc. Thus, this paper would compare & contrast the critical causes for non-conformity of the PAs arising from ICTAD formula method and true fluctuation calculation.

## **2 LITERATURE SURVEY**

PA clauses for a particular contract allow the contractor to submit a more realistic bid without adding an arbitrary mark-up for escalation. Price escalation is the change in cost or price of specific goods or services in a given economy over a period. The escalation in price of units reflects the inflationary trends in the economy (Chaphalkaretal & Sandbhor, 2012). A brief overview of the practice of fluctuation adjustment in other countries, confirms that there is no single fluctuation formula that suits all jurisdictions, nor a single formula to satisfy all employers and contractors (Construction industry council, 2011).

In 1973, the National Economic Development Office in UK (NEDO) established systematic PAFs, namely Baxter Formula for civil engineering works, Osborne Formula for other building works and Bespoke formula used for the specialist engineering installations (Abeysekara, 1997). These formulas operate the all the BOQ items allocated for work categories and the balance of adjustable work such as preliminary and general items, water, insurance, adjustments on the tender summary, provisional sums and work or items excluded from formula adjustment. The PA for balance of adjustable work is calculated using another formula (JCT, 2011).

Present methods for PA calculation can be divided into two approaches. First approach is the FIDIC formula for PA calculation (FIDIC, 2005). Other Asian countries, e.g. India and Pakistan, are also practicing a PA formula similar to the FIDIC formula. The responsible authority for India is Central Public Works Department (CPWD, 2007). Also, in Pakistan, the Pakistan Engineering Council (PEC) is responsible for the PA formula for contract works (PEC, 2005). Second approach is developed by the Department of Public Works (DPW) of South Africa and the relevant indices published by the Department of Statistics South Africa (Association of South African quantity surveyors, 2013). With reference to this, generally, there are two types of fluctuation calculating methods, namely conventional method and price index based formulae (formula method).

## **3 METHODS FOR PRICE ADJUSTMENT**

In conventional method, at the time of tender the contractor will be provided with a list of the principal materials, plant and labour to be used in the contract and is expected to insert the unit prices for those resources on which bill rates are based. Then, comparing these base prices with the current prices at the time of each interim payment, the price fluctuation of selected resources will be computed (Samaraweera, 2013). Conventional method is a fully reimbursement method.

Formula method adjusts the price fluctuation based upon price indices at tender month and date of measurement. PAs will be made in accordance with the change in the Price Index (PI) of relevant resources within the contract period published by the responsible authority in the country. The Price Fluctuation Formula (PFF) will be determined by

comparing the difference between the PI in effect for the base month and current month. Formula method is a partially reimbursement method.

### 3.1 ICTAD Fluctuation Formula

The responsible authority for both formula and the PIs in Sri Lanka is the ICTAD (ICTAD, 2007). The PIs for materials, labour, machineries and fuel are published by the ICTAD every month. There are 46 categories of materials from M1 to M46, 3 categories of labour from L1 to L3, 2 categories of machineries of P1, P2 and fuel category of P3 published in the ICTAD PI bulletin (ICTAD, 2013). In the development of this formula, two assumptions have been made, namely inputs uniformly distributed throughout the contract (Mel, 2013) and 90% of contract value is major costs and 10% of contract value is minor costs, i.e. 90% cost recovered at 40% of BOQ items (ICTAD, 2008). Latter assumption is based on the 80-20 concept of the construction economics. The general formula (contract value more than 10 Million Rupees) for PA reference to the “ICTAD formula method for adjustments to contract price due to fluctuation in prices” is as follows (ICTAD, 2008).

$$F = \frac{0.966(V - V_{na})}{100} \cdot \sum_{\text{all inputs}} P_x \cdot \frac{(I_{xc} - I_{xb})}{I_{xb}} \quad (1)$$

Where;

$$\sum_{\text{all inputs}} P_x \cdot \frac{(I_{xc} - I_{xb})}{I_{xb}} = \text{Fluctuation Index (Input Value Factor)}$$

## 4 METHODOLOGY

### 4.1 Methodology Adopted

The methodology used in this study is represented in the form of a flow chart diagram in Figure 1. The analysis of the research problem is basically divided into three separate analyses namely data analysis, sensitivity analysis and statistical analysis. Data analysis represents the evaluation of the four selected construction projects with the model project for the real fluctuation scenario. As shown in Figure 2 sensitivity analysis demonstrates the investigation of the four selected construction projects for the six hypothetical fluctuation scenarios. The analyzed data gathered from both data and sensitivity analyses, finally, is evaluated under the statistical analysis to find the suitable modification for the ICTAD price adjustment formula. The short summary of the step by step approach for the methodology used in this study is as follows.

- a) Collection of master BOQs, master programmes (bar charts), work norms for BOQ items and interim payments (monthly bills).
- b) Preparation of resource schedules for materials, labour and plant.
- c) Calculation of PA for each interim payment according to the conventional method and according to the ICTAD formula method separately.
- d) Assessment of the effect of price indices used in the ICTAD formula with the true changes of prices throughout the span of the project subjecting different time frames in the master programme.

- e) Determination of the closeness of ICTAD formula to the true fluctuation amount obtained by conventional method.
- f) Investigation of relationship between FC with CAF and RAF considering selected projects for real and hypothetical price fluctuation conditions.

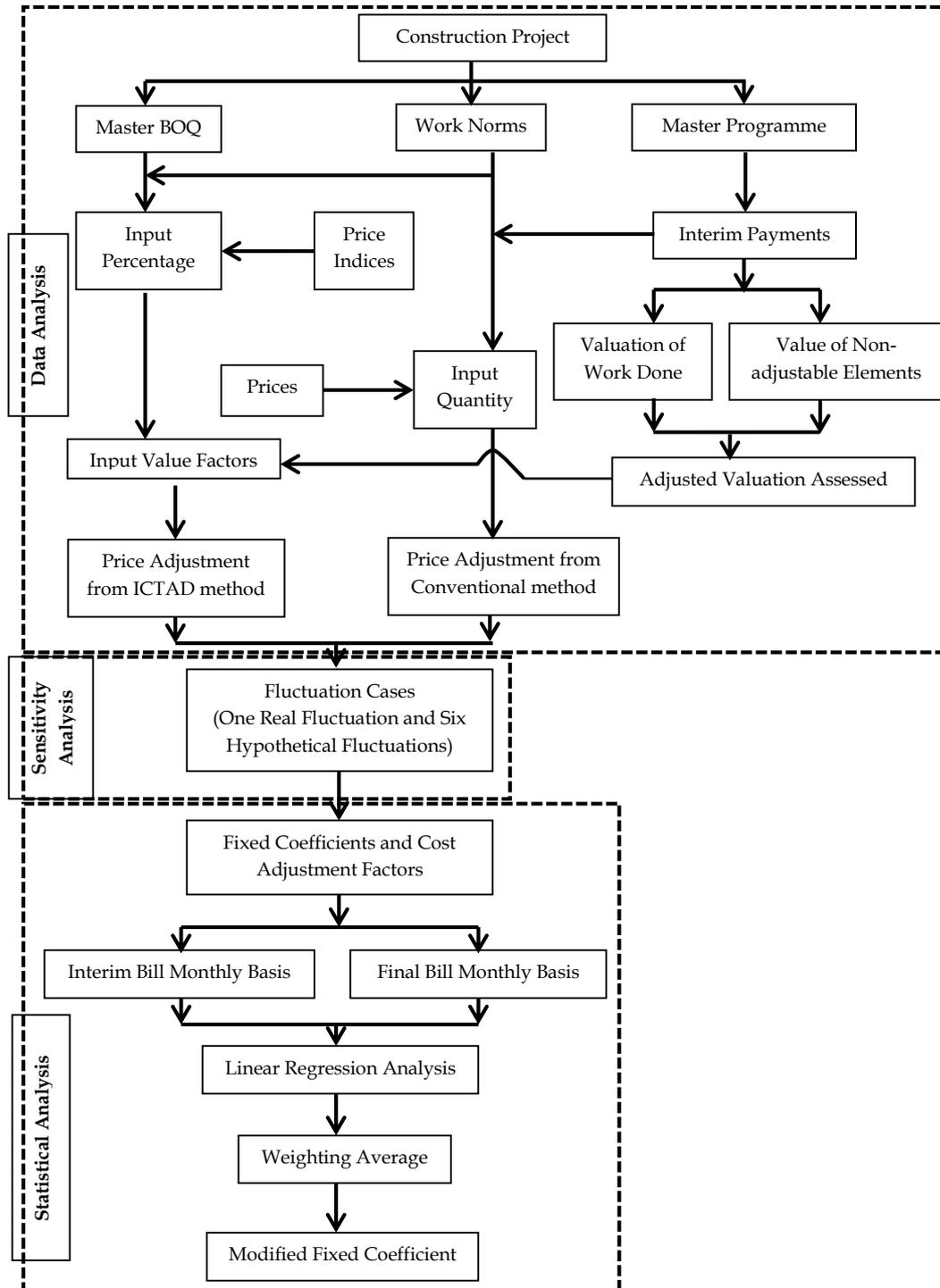


Figure1 Flow chart for research problem analysis

- g) Development of mathematical relationship between FC and CAF with relevant to graphical form using computed data from earlier sensitivity analysis.
- h) Determination of modified FC for the current ICTAD formula with the help of the statistical analysis and the weighting averages to increase the closeness of the ICTAD price adjustment to the true price adjustment.

#### 4.2 Data, Sensitivity and Regression Analysis

Analysis of data is a process of inspecting, cleaning, transforming, and modelling data with the goal of discovering useful information, suggesting conclusions, and supporting decision-making (Bhatnagar, 2014). In this study data analysis will be carried out by using linear regression which is one of the most common methods categorized under the statistical analysis.

Sensitivity analysis of the ICTAD price fluctuation formula is the study of how the uncertainty in the output of a mathematical formula, i.e. ICTAD formula, can be apportioned to different sources of uncertainty in its inputs, i.e. input percentages, price indices, valuation assessed etc., with reference to the true PA (Dimov et. al., 2015).

Simple linear regression aims to find a linear relationship between a response variable and a possible predictor variable by the method of least squares (Montgomery et. al., 2012). The predictable variable is known as the criterion variable and is referred to as Y. The base variable is called the predictor variable and is referred to as X. In simple linear regression, the predictions of Y when plotted as a function of X form a straight line (Lawrence, 2009).

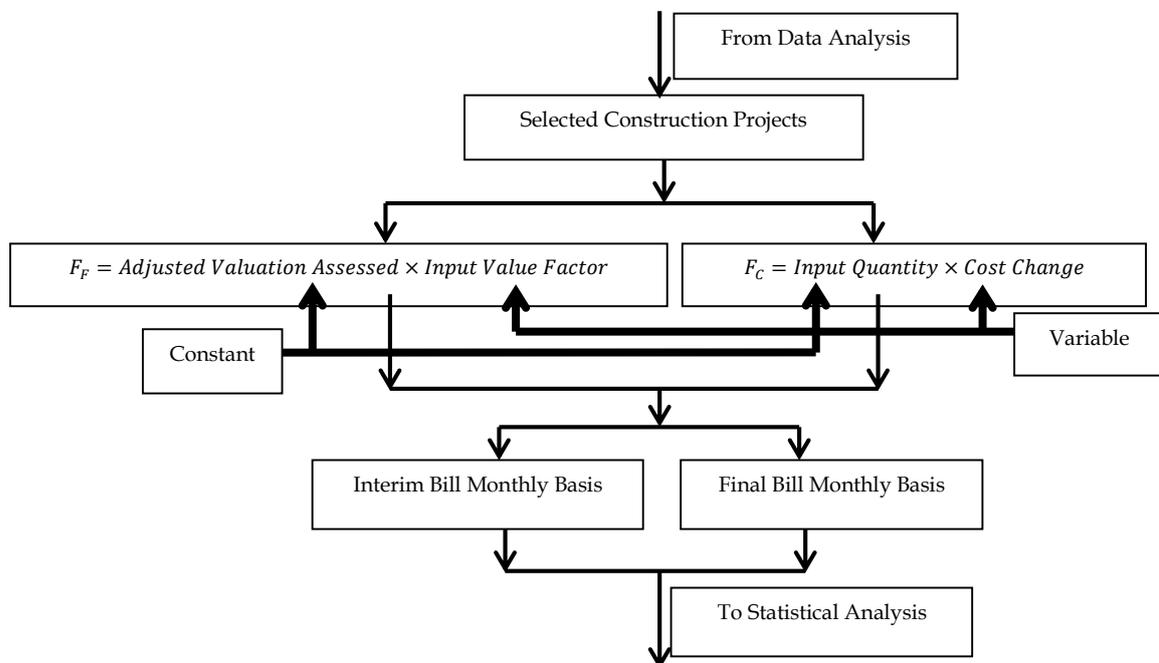


Figure 2 Flow chart for sensitivity analysis of selected projects

## 5 RESULTS AND DISCUSSION

### 5.1 Data Analysis

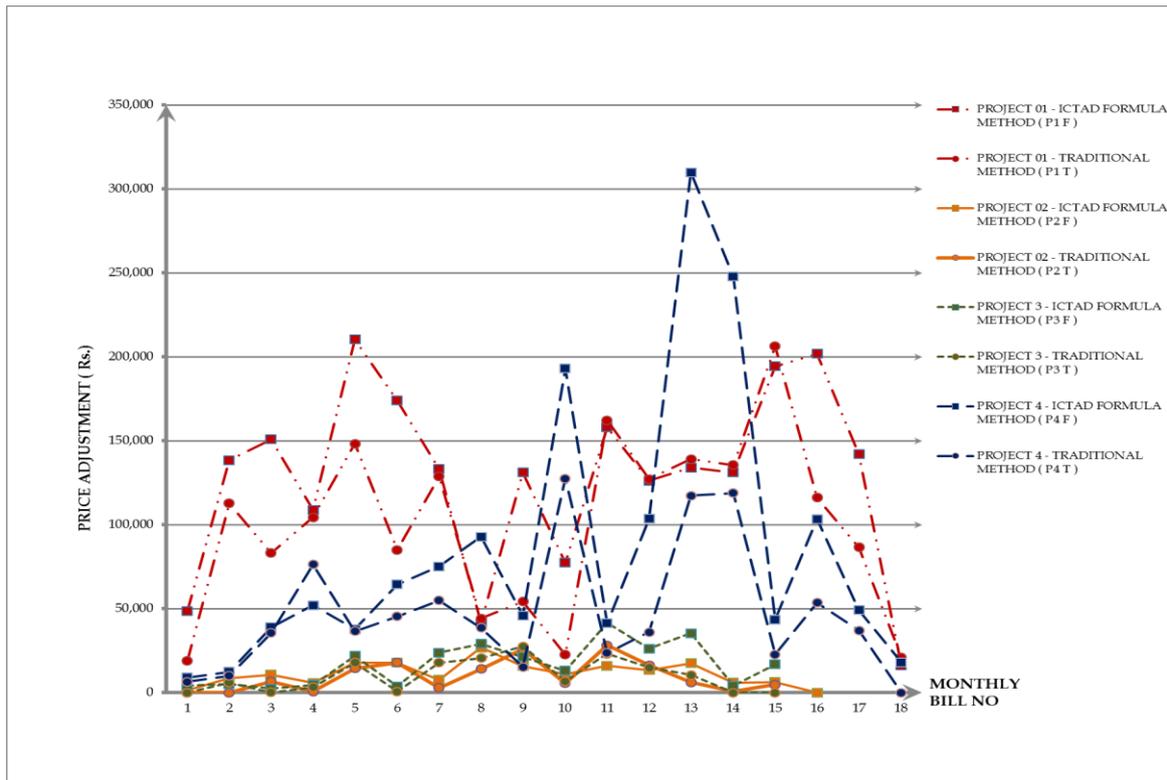
Data analysis is carried out to find the relationship between ICTAD price adjustments & true PAs. This section consists of several activities namely collection of master BOQs, collection of master programmes (bar charts), preparation of work norms, collection of interim payments, determination of input percentages, calculation of price indices and input value factors, computation of valuation of work done and value of non-adjustable elements, determination of PA using ICTAD method, calculation of input quantities, computation of change of costs and determination of PA using conventional method.

### 5.2 Results and Discussion of Data Analysis

The analysis of four numbers of long term construction projects gave the following results as indicated in Table 1 and Figure 3.

**Table 1 Comparison of ICTAD formula and conventional methods**

BILL NO	PRICE ADJUSTMENT								
	PROJECT NO. 1		PROJECT NO. 2		PROJECT NO. 3		PROJECT NO. 4		
	ICTAD FORMULA METHOD	TRADITIONAL METHOD	ICTAD FORMULA METHOD	TRADITIONAL METHOD	ICTAD FORMULA METHOD	TRADITIONAL METHOD	ICTAD FORMULA METHOD	TRADITIONAL METHOD	
1	48,720.10	19,090.30	1,490.56	0.00	4,257.68	0.00	9,005.79	6,464.88	
2	138,470.84	112,759.32	8,582.77	0.00	5,219.77	5,931.00	12,419.86	10,029.25	
3	150,933.03	83,214.94	10,770.71	6,702.50	2,387.64	255.00	39,026.44	35,545.20	
4	108,906.25	104,494.50	5,863.48	735.80	4,565.30	3,251.30	52,068.46	76,381.31	
5	210,402.71	148,342.00	17,697.56	14,451.25	21,913.48	17,873.24	37,729.07	36,616.24	
6	173,982.80	85,118.44	17,938.51	17,816.07	3,854.89	700.88	64,458.33	45,422.40	
7	133,222.69	128,715.20	7,676.48	2,867.85	23,855.93	17,832.78	75,270.18	54,914.24	
8	41,747.44	44,288.50	26,914.70	14,170.61	29,175.63	20,596.31	92,911.12	38,634.98	
9	131,094.38	54,199.00	15,868.78	25,947.01	21,309.96	27,625.69	45,997.20	15,290.37	
10	77,455.01	22,576.73	10,879.61	5,671.89	13,128.44	6,803.20	193,020.89	127,570.94	
11	158,028.94	162,276.84	15,948.41	28,327.26	41,571.97	23,203.90	41,294.82	23,680.13	
12	126,254.77	127,184.50	13,549.58	16,440.19	26,271.92	14,998.91	103,608.19	36,067.08	
13	133,952.31	139,202.40	17,629.11	6,162.56	35,364.51	10,565.09	309,947.83	117,342.24	
14	131,102.24	135,512.63	6,024.80	650.08	4,198.09	0.00	247,718.54	118,982.47	
15	194,387.14	206,310.33	6,412.01	4,712.42	16,930.68	0.00	43,574.23	22,839.50	
16	201,945.42	116,158.70					103,410.82	53,653.95	
17	141,967.69	86,663.55	<b>PROJECTS COMPLETED IN 15 MONTHS</b>					49,108.80	37,096.83
18	16,269.82	21,065.10					18,021.86	0.00	
<b>TOTAL</b>	<b>2,318,843.57</b>	<b>1,797,172.98</b>	<b>183,247.07</b>	<b>144,655.49</b>	<b>254,005.89</b>	<b>149,637.29</b>	<b>1,538,592.43</b>	<b>856,531.99</b>	
<b>DIFFERENCE</b>	<b>521,670.60</b>		<b>38,591.58</b>		<b>104,368.60</b>		<b>682,060.44</b>		
<b>% OF OVER-ESTIMATE</b>	<b>29.03</b>		<b>26.68</b>		<b>69.75</b>		<b>79.63</b>		



**Figure 3 Price fluctuation with time in selected projects**

Only the final summary of the selected project nos. 1, 2, 3 and 4 is represented here as a form of table without indicating other information and tabulations such as master BOQs, programmes, interim payments, input percentage tables etc. These results were also observed in the model project analysis and hence these selected projects further justified the pre-founded important points which are the base for this research problem analysis.

According to the data analysis adopted for selected projects as well as the model project a considerable difference is observed between the PA amount calculated by means of ICTAD method and conventional method. This fluctuation occurs due to the several contradictions between the formulae with relevant to the true situation. Analysis of model and selected projects revealed the following key points.

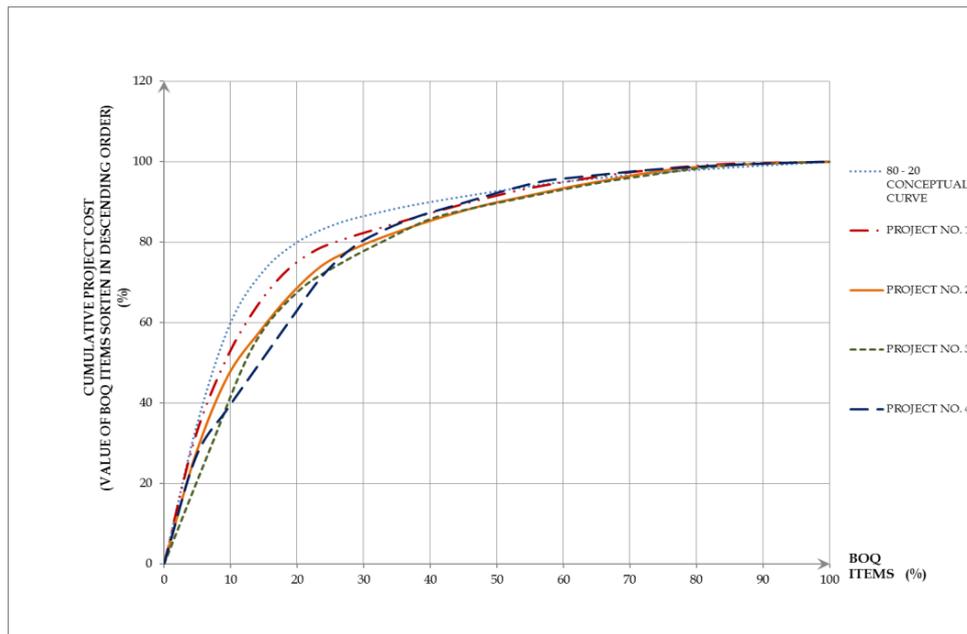
- a) Assumption of uniformly distributed input percentages for a particular project throughout the project duration is not valid.
- b) Assumption of 90% of cost recovered at 40% BOQ items for a particular contract is not valid for every project.
- c) Cost adjustment factor (K) used in the derivation has a fixed value of 15% which allows for the profit (P) & overheads (OH) of the contractor. But this margin ranges generally from 15% to 35% and cannot be fixed for every project. The analyzed two projects consist of 22% of P & OH and therefore ICTAD formula need to be adjusted according to that.

- d) Rest adjustment factor (R) facilitate the PA indirectly for the minor inputs and in the derivation it is assumed as 10%. However, depending on the type of the construction this factor varies accordingly and therefore it is not fair to fix it for every contract.

One of the major parameters that affect the ICTAD price adjustment is the input percentage and this value depends on an assumption that 90% of cost is recovered by 40% of BOQ items. This is based on the 80-20 concept of construction materials, i.e. each individual project, 80% of the total cost is found in 20% of the major items of materials (Bent, 1996). Basically, this assumption is not valid for every project and this can be clearly understood reference to Table 2 and Figure 4.

**Table 2 Actual variation of cost of BOQ items in selected projects**

PROJECT NO. 1		PROJECT NO. 2		PROJECT NO. 3		PROJECT NO. 4	
CUMULATIVE GROUP (%)	% OF CUMULATIVE AMOUNT	CUMULATIVE GROUP (%)	% OF CUMULATIVE AMOUNT	CUMULATIVE GROUP (%)	% OF CUMULATIVE AMOUNT	CUMULATIVE GROUP (%)	% OF CUMULATIVE AMOUNT
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4.55	30.72	4.76	27.29	6.67	27.60	4.76	26.51
9.09	50.06	9.52	46.56	13.33	54.02	9.52	38.56
13.64	63.31	14.29	57.64	20.00	67.58	14.29	49.75
18.18	72.54	19.05	67.08	26.67	74.85	19.05	60.89
22.73	77.98	23.81	74.30	33.33	80.59	23.81	71.67
27.27	80.91	28.57	78.40	40.00	85.77	28.57	78.98
31.82	83.23	33.33	81.58	46.67	88.58	33.33	83.26
36.36	85.48	38.10	84.33	53.33	90.87	38.10	86.40
40.91	87.67	42.86	86.80	60.00	93.13	42.86	88.75
45.45	89.71	47.62	89.04	66.67	95.18	47.62	91.09
50.00	91.63	52.38	90.77	73.33	96.81	52.38	93.36
54.55	93.34	57.14	92.45	80.00	98.34	57.14	95.24
59.09	94.68	61.90	94.07	86.67	99.35	61.90	96.16
63.64	95.93	66.67	95.50	93.33	99.70	66.67	96.97
68.18	97.04	71.43	96.91	100.00	100.00	71.43	97.78
72.73	97.90	76.19	98.11			76.19	98.39
77.27	98.64	80.95	98.85			80.95	98.87
81.82	99.22	85.71	99.25			85.71	99.28
86.36	99.60	90.48	99.59			90.48	99.57
90.91	99.78	95.24	99.87			95.24	99.85
95.45	99.91	100.00	100.00			100.00	100.00
100.00	100.00	<b>ONLY 21 COST GROUPS</b>		<b>ONLY 15 COST GROUPS</b>		<b>ONLY 21 COST GROUPS</b>	



**Figure 4 80-20 Concept with actual variation in selected projects**

The fluctuation calculated using the formula of all selected construction projects including the model project demonstrated a considerable deviation from the true fluctuation due to the unbalance of computed input percentages. Also, the assumption i.e. input percentages are uniformly distributed throughout the project duration, is also misleading the PA amounts since this assumption is based on the period of use of particular input with corresponding input quantities. As an example, project no. 4 gave 79.6% of over-estimate due to the non-uniformly distributed input percentages. Following are some inputs in this project no. 4 which are subjected to additional payment under the ICTAD price adjustment.

Bricks - Only used in 6th, 7th and 8th months (duration 3 months), but the price index varies since the start of 1st month to the end of 18th month. When the price indices are changed the input value factor corresponding to this input gets activated producing extra cost on the total PA amount. Therefore, client must pay some additional amount to the contractor which the contractor is not actually entitled. This additional amount is Rs. 19,004.87. However, the true PA amount corresponding to the 3 month duration is Rs. 3,049.71.

3/4" Metal - Only used during 1st to 8th months (duration 8 months), but the price index varies since the start of 1st month to the end of 18th month. Therefore, the client must pay an additional amount of Rs. 12,398.33 to the contractor instead of the true reimbursement of Rs. 4,034.66.

Steel Reinforcements - Only used during 1st to 6th months (duration 6 months), but the price index varies since the start of 1st month to the end of 18th month. The true reimbursement must be Rs. 72,517.79, but additionally the client need to pay an amount of Rs. 572,811.46 to the contractor.

The total additional payment which is paid under the ICTAD price adjustment method due to the non-uniformly distributed input percentages is Rs. 654,954.57. This amount has a value of 76.5% of over-estimate and from this it is clear that the non-uniformly distributed input percentages seriously affect the ICTAD price adjustment.

The CAF and the RAF which are used in the derivation of ICTAD formula have some shortcomings due to its non-adjustability of the value. These two factors are assumed as constant for every project taking their values as 15% for CAF and 10% for RAF. These two factors are directly related to the FC, i.e. 0.966, in the current ICTAD formula and when these two factors are changed, the ICTAD price adjustment amount can be over-estimated in most cases and under-estimated in very few cases. The ICTAD publications define the CAF, i.e. K, as the factor which denotes the profit of the contractor included in the BOQ items, but practically this factor cannot be fixed for each and every construction project due to the following reasons investigated in this data analysis.

- a) The selected construction projects consist of various overall profit margins depending on the type of the construction project. This margin varies from 15% to 35% and therefore the use of current ICTAD fixed coefficient of 0.966 which is based on  $K=15\%$  is not reliable.
- b) The contractor tends to use front loaded BOQ items and/or back loaded BOQ items when bidding and this will also make variable K values throughout the contract period. However, when calculating PA amount due to fluctuation by current ICTAD formula, for all interim payments the valuation assessed multiplied by same FC, i.e. 0.966. But the valuation assessed contributed by different CAFs and therefore an average value must be used to address this issue.

Also the RAF, i.e. R, is defined by the ICTAD as the factor which represents the PA corresponding to the minor inputs reimbursed indirectly with the major input PA amount. This factor is fixed in the current ICTAD formula and taken as 10% for all projects. On the other hand major inputs are considered to be 90%. But in the data analysis it is found that the observation of the exact 90% boundary to separate major and minor inputs in the computation of input percentages is impossible. As an example, for project no. 1 this value is taken as 91.63% and for project no. 2 this value is considered as 90.77%. Sometimes this boundary is slightly higher than 90% and sometimes it is slightly lower than 90%. Therefore, the constant RAF in the computation of input percentages reduces the sensitivity of the ICTAD price adjustment formula.

### **5.3 Sensitivity Analysis**

Sensitivity analysis is carried out to estimate the accuracy of the ICTAD formula method for the PAs. As mentioned earlier, under the sensitivity analysis above selected four numbers of construction projects were further analyzed with respect to the periods which the price fluctuations may occur. As shown in Figure 5, six hypothetical fluctuation scenarios are used to assess the sensitivity of the ICTAD price adjustment formula and these scenarios.

As an example, scenario 1 demonstrates the first phase has no price fluctuation relative to the base month, second phase and third phase have equal price fluctuations; therefore it is named as constant; rise; rise. Similarly, scenario 2 demonstrates the first and second phases have no fluctuation, but third phase has a price fluctuation. For all selected projects one phase means a 1/3 of project duration and therefore for project no. 1, 4 one phase equals to 6 months since total project duration is 18 months and for project no. 2, 3 that is equal to 5 months since project duration is 15 months. The calculations relevant to the sensitivity analysis are similar to the calculations of the data analysis.

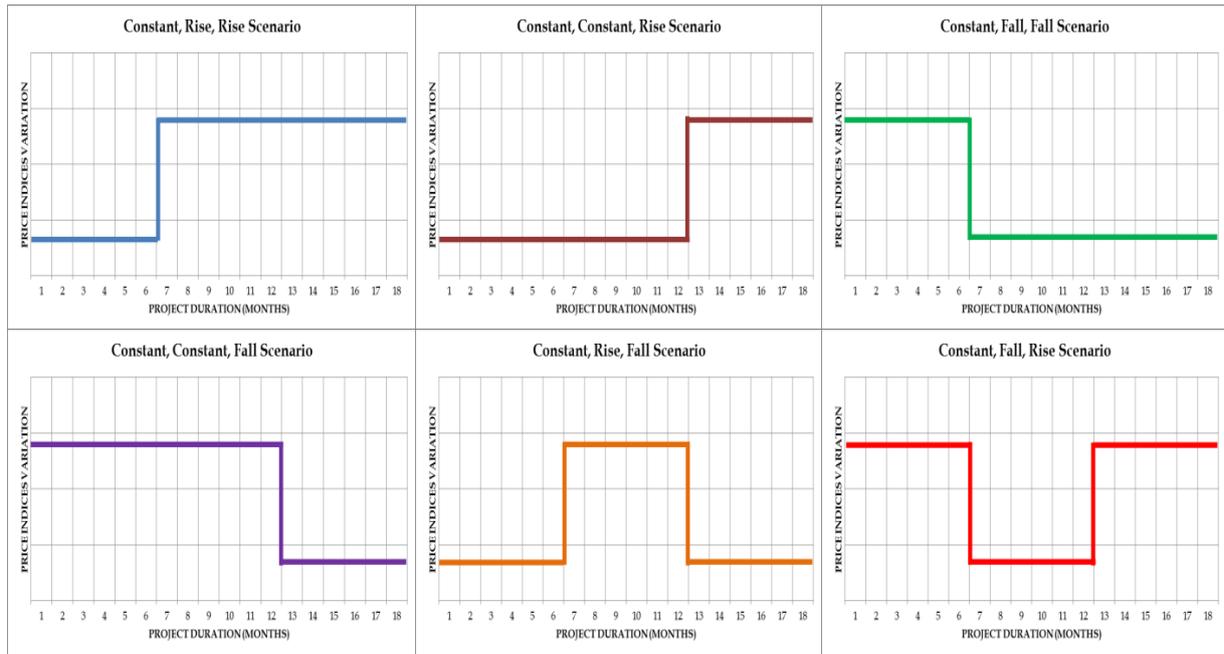


Figure 5 Six hypothetical fluctuation scenarios

## 5.4 Results and Discussion of Sensitivity Analysis

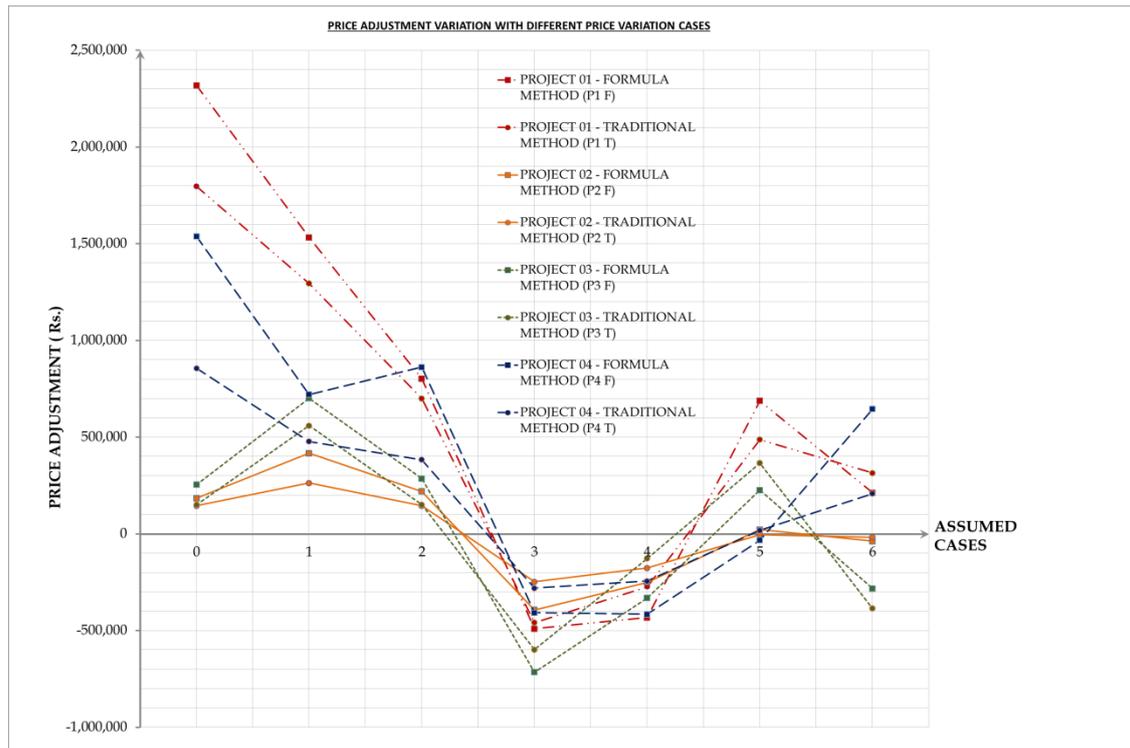
Table 3 and Figure 6 only represent the price fluctuation in different fluctuation scenarios for four numbers of selected projects in final bill monthly basis, i.e. fluctuation at the end of project duration. In Table 3 and Figure 6, case - 0 represent the real fluctuation observed throughout the project duration. The observed total PAs in some cases got negative and in some cases got positive. The latter represent the most common case i.e. client needs to pay corresponding PA to the contractor. But the negative fluctuation (as an example project no. 1, case 3 and 4) represents the necessity of payment of PA to the client by the contractor. This sensitivity analysis reveals the following results.

- 1) When the amount of PA is increased, the difference between the formula adjustment and the true adjustment also increased. This can be observed in project no. 1-fluctuation cases 0, 1, 2, project no. 2-fluctuation cases 0, 1, 2 and project no. 3-fluctuation cases 1, 2.

- 2) When the prices or price indices increased relative to their bases then the total fluctuation gets positive value resulting cost reimbursement to the contractor from the client. This can be observed for 0, 1 and 2 fluctuation cases for all four projects.
- 3) When the prices or price indices decreased relative to their bases then the total fluctuation gets negative value resulting cost reimbursement to the client from the contractor. This can be seen in all four projects for fluctuation cases 3 and 4.
- 4) In most cases either positive or negative PA, the ICTAD price adjustment overestimates the true price adjustment. This is demonstrated in all four projects in fluctuation cases 0, 1, 2, 3 and 4.

**Table 3 Price adjustment in different fluctuation scenarios**

CASE	PRICE ADJUSTMENT							
	PROJECT NO. 1				PROJECT NO. 2			
	ICTAD FORMULA METHOD	TRADITIONAL METHOD	DIFFERENCE	% OF OVER-ESTIMATE	ICTAD FORMULA METHOD	TRADITIONAL METHOD	DIFFERENCE	% OF OVER-ESTIMATE
0	2,318,843.57	1,797,172.98	521,670.60	29.03	183,247.07	144,655.49	38,591.58	26.68
1	1,532,243.26	1,294,083.19	238,160.07	18.40	417,016.22	262,277.94	154,738.28	59.00
2	801,870.86	699,578.82	102,292.04	14.62	218,842.39	145,486.63	73,355.76	50.42
3	(491,061.74)	(458,673.85)	(32,387.89)	7.06	(393,442.52)	(247,909.90)	(145,532.62)	58.70
4	(432,976.63)	(273,855.44)	(159,121.19)	58.10	(250,352.90)	(177,052.51)	(73,300.39)	41.40
5	687,256.63	486,875.93	200,380.69	41.16	21,745.46	(4,172.84)	25,918.30	(621.12)
6	212,252.83	314,587.99	102,335.16	32.53	(37,874.40)	(17,456.16)	(20,418.24)	116.97
CASE	PRICE ADJUSTMENT							
	PROJECT NO. 3				PROJECT NO. 4			
	ICTAD FORMULA METHOD	TRADITIONAL METHOD	DIFFERENCE	% OF OVER-ESTIMATE	ICTAD FORMULA METHOD	TRADITIONAL METHOD	DIFFERENCE	% OF OVER-ESTIMATE
0	254,005.89	149,637.29	104,368.60	69.75	1,538,592.43	856,531.99	682,060.44	79.63
1	701,096.83	559,696.26	141,400.57	25.26	720,223.87	477,313.86	242,910.01	50.89
2	285,984.37	150,649.00	135,335.37	89.83	861,926.79	383,054.22	478,872.57	125.01
3	(714,942.95)	(598,385.38)	(116,557.57)	19.48	(408,098.17)	(280,655.07)	(127,443.10)	45.41
4	(331,563.71)	(127,408.50)	(204,155.21)	160.24	(415,322.05)	(244,480.29)	(170,841.76)	69.88
5	225,964.35	365,592.96	139,628.61	38.19	(32,693.14)	17,475.35	(50,168.49)	(287.08)
6	(282,554.44)	(385,296.18)	(102,741.74)	26.67	645,118.99	207,491.11	437,627.88	210.91



**Figure 6 Price adjustment in different fluctuation scenarios**

- 5) However, when there is rise and fall of the prices and price indices throughout the project duration, there is a tendency to become ICTAD price adjustment smaller than the true price adjustment due to the lack of sensitivity of the formula to the true fluctuation. Out of the 28 observations only 4 observations represented this issue which can be negligible.
- 6) Valuation assessed is another governing factor which affects the ICTAD price adjustment and the non-realistic amounts may result over-estimates or under-estimates of the PA computed using ICTAD formula. This observation can be experienced when comparing the monthly bill PA values for different fluctuation scenarios. This can happen in the ICTAD price adjustment in any of the following two ways.
  - a) If there is a particular month on which the valuation of work done contributing a very few amount of items liable to the PA, but the majority contributed by the items not liable to the PA, then the contractor would receive an extra amount of payment even with the small input value factors. This results the over-estimate.
  - b) If there is a particular month with the large amount of non-adjustable elements, then the valuation assessed gets small even with the considerable amount of valuation of work done. This results a reimbursement of less PA to the contractor or client even with the large value of input factors. This results the under-estimate.

Therefore, there should be a proper consideration when evaluating the valuation assessed in the ICTAD price adjustment formula.

- 7) In some fluctuation scenarios, PA computed by ICTAD formula shows a positive PA while true PA is negative. This reveals again that the cost to be reimbursed from contractor to the client, but due to the less sensitivity of the ICTAD formula client need to suffer by paying an additional amount to the contractor. This can be seen in project no. 2-fluctuation case 5. Also the vice versa situation of this issue can be observed in project no. 4-fluctuation case 5.

## 5.5 Statistical Analysis

Statistical analysis is carried out to propose a modification to increase the accuracy of ICTAD formula. It was justified from both data analysis and sensitivity analysis; there is a large over-estimation of the amount of PA calculated by the ICTAD formula. Therefore, the results which are collected from the sensitivity analysis including results gathered in the data analysis can be addressed by changing the FC of the current ICTAD formula to suit the selected fluctuation scenarios with different profit margins. Also, this modified FC may have some flexibility to the non-uniformly distributed input percentages. The calculation of  $x$  and  $K$  values for six different price fluctuation scenarios with corresponding real price fluctuation case for four numbers of selected construction projects provide series of observations.

The  $x$  and  $K$  values are computed considering two situations namely interim bill basis, i.e. at the end of every bill month FC and CAF will be calculated, and final bill basis, i.e. at the end of project FC and CAF will be calculated. In interim bill basis, FC is computed for each bill using the following relationship.

$$x = \frac{\frac{100.F_C}{(V-V_{na})}}{\sum_{\text{all inputs}} P_x \cdot \left(\frac{I_{xc} - I_{xb}}{I_{xb}}\right)} \quad (2)$$

In final bill basis computation FC can be determined by using following relationship.

$$x = \frac{0.966.F_C}{F_F} \quad (3)$$

After calculating these  $x$  values for all interim bill basis and final bill basis for each scenario in all selected projects, following relationship is used to compute the corresponding  $K$  values where  $R$  can be taken as 10%.

$$K = \frac{100}{\frac{x}{100} \cdot (100 - R)} - 100 \quad (4)$$

At the end of x and K computations it can be seen that the numbers of observations for four numbers of projects varied due to the zero fluctuations of the conventional method and the total numbers of observations of 286 reduces to 262. Also, practically it is not possible to have negative K value and/or a K value which is greater than 100% in the price fluctuation calculations.

Therefore, observations of K values which are negative and/or greater than 100%, were considered as outliers and hence rejected and remaining observations are taken for the statistical analysis (Taylor & Sihon, 2004). Hence, following numbers of observations are used to carry out the statistical analysis in terms of interim bill basis.

- a) Project no. 1 – 50 nos.
- b) Project no. 2 – 25 nos.
- c) Project no. 3 – 29 nos.
- d) Project no. 4 – 35 nos.

Therefore, the total numbers of observations of 262 was further reduced to 139 rejecting 123 numbers of observations due to the above mentioned reason. Also, the total numbers of observations for final bill basis analysis is 28. However, these observations reduced to 17 after the rejection of the unsuitable K values. Therefore, in this calculation only 17 observations can be evaluated since the computation of FC based on the weightages of both total conventional PA and total formula PA at the end of the project duration.

From the data analysis and the sensitivity analysis, seven different fluctuation scenarios were obtained and these scenarios yield 139 numbers of x and K values for all projects on the basis of monthly fluctuation. Also, for all selected projects 17 numbers of x and K values obtained on the basis of total fluctuation. Therefore, to conduct a regression analysis, the following two data sets can be used.

Data Set no. 1 – Interim bill basis FC and CAF values having 139 observations

Data Set no. 2 – Final bill basis FC and CAF values having 17 observations

The two data sets mentioned above provide two trend lines which are the most suitably fixed to the observed fluctuation between the FC and CAF may yield two simultaneous mathematical relationships. Solving these equations in weighted average basis, the proposed fixed coefficient can be computed. The summary of the statistical analysis based on the interim bill basis and final bill basis for selected projects are represented in Table 4.

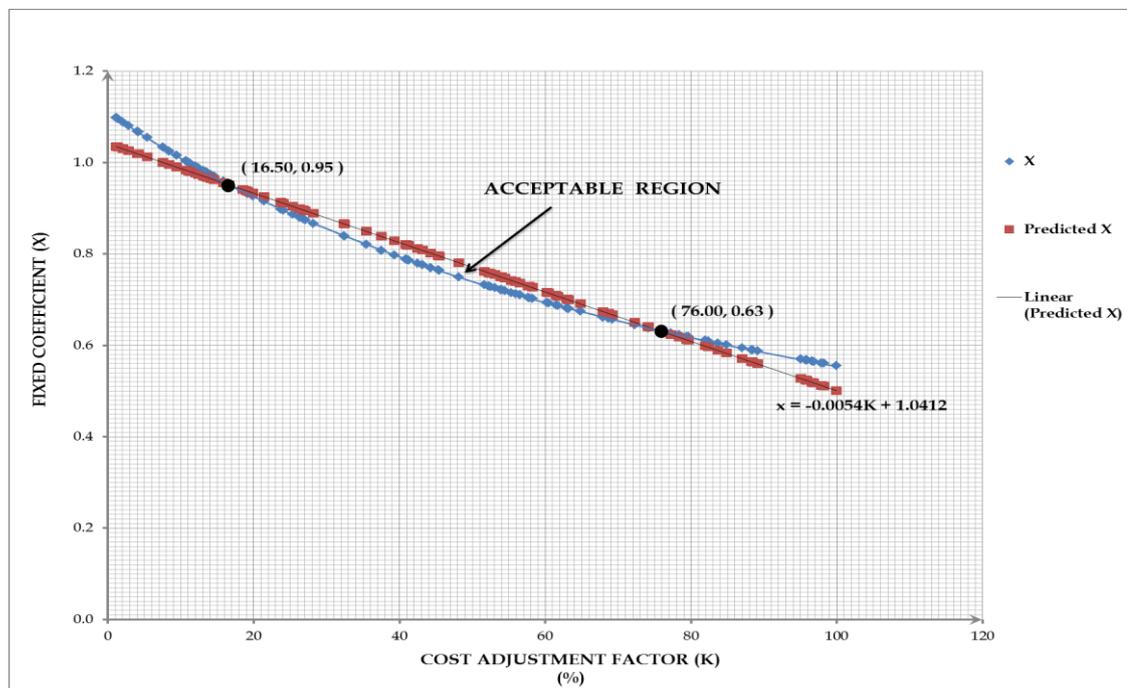
This analysis demonstrated the calculated multiple R, R squared and adjusted R squared for both models are very closer to 1. Therefore, it is justified that the linear dependency between x and K and the goodness of fit of the two regression models to observed fluctuation (Gwet, 2010).

**Table 4 Summary of regression statistics for selected projects**

Interim Bill Basis – For Selected Projects		Final Bill Basis – For Selected Projects	
Regression Statistics		Regression Statistics	
Multiple R	0.9851	Multiple R	0.9895
R Square	0.9704	R Square	0.9791
Adjusted R Square	0.9702	Adjusted R Square	0.9777
Standard Error	0.0278	Standard Error	0.0180
Observations	139	Observations	17

Figure 7 and Figure 8 show the graphs in between the K variable and x based on interim bill month and final bill month respectively. The general fluctuation in both graphs is non-linear but this non-linear fluctuation can be fitted to the linear fluctuation as indicated in the same figures. These new two sets of new trend lines provide two simultaneous mathematical relationships as shown in the same figures.

The proposed modified fixed coefficient can be computed by using the weighted averages and this value is equal to the 0.757. Also, according to the modified x value, the corresponding K value can be calculated based on weighted averages and this value is equal to 51.2%. The allowable limit of RAF corresponding to both new x and K values can be calculated as 12.6%.



**Figure 7 Variable K-line fit plot for interim bill basis – for selected projects**

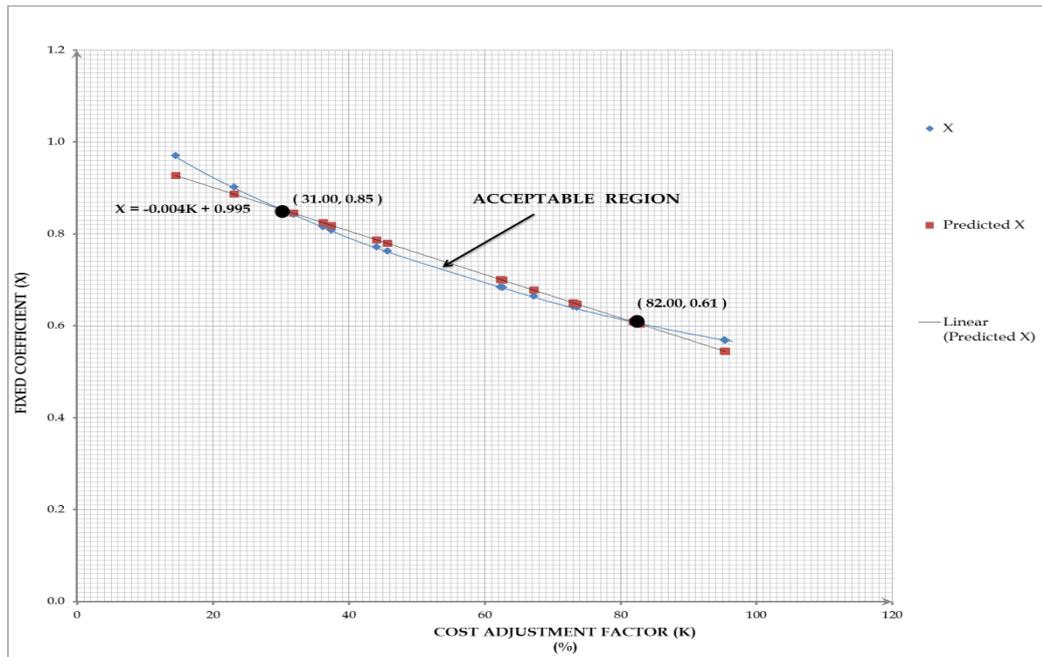


Figure 8 Variable K-line fit plot for final bill basis - for selected projects

## 5.6 Results and Discussion of Statistical Analysis

The statistical analysis lead to a new fixed coefficient to replace the current ICTAD fixed coefficient and the use of this modified fixed coefficient improves the sensitivity of the ICTAD price fluctuation formula while reducing the large over-estimate comparatively. Hence the modified ICTAD price adjustment formula is as follows.

$$F = \frac{0.757(V - V_{na})}{100} \cdot \sum_{\text{all inputs}} P_x \cdot \frac{(I_{xc} - I_{xb})}{I_{xb}} \quad (5)$$

Also, it is clear that this modified FC allows a 51.2% of contractors' average profit margin ( $K = 51.2\%$ ) throughout the project duration instead of the constant 15% in current FC. Furthermore, this modified FC allows a 12.6% of minor inputs ( $R = 12.6\%$ ) to pay in the ICTAD price adjustment indirectly. But in the current FC, only 10% is considered.

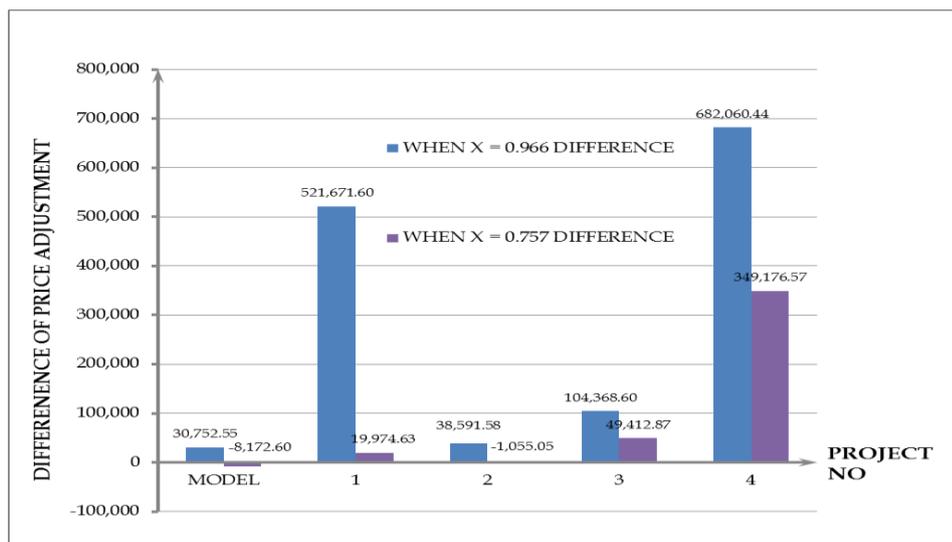
According to the ICTAD price adjustment formula, the  $F_F \propto x, (V - V_{na}), (I_{xc} - I_{xb}), P_x$  and  $x \propto R, (1/K)$ . Therefore, modification of  $x$  in the formula may address the  $R$  and  $K$  directly. Also, the analysis of several projects in different fluctuation scenarios with different levels of input usage i.e. construction materials usage and price indices changes addressed the valuation assessed and the price indices. The combined effect of all these factors analyzed logically through a statistical analysis gave the following result.

Modified FC	=	0.757
Allowable CAF	=	51.2%
Allowable RAF	=	12.6%

In the current ICTAD formula above values are 0.966, 15% and 10% respectively. Since the current ICTAD price adjustment formula always over-estimated the PA, the modified FC reduced up to 0.757. But 15% of CAF increases up to 51.2% to allow the effect of front end and back end loading of the BOQ items. The 10% of RAF is also increased by a small value up to 12.6% to allow the minor inputs issue. The effect of this modified FC is represented in Table 5 and Figure 9.

**Table 5 Comparison of modified FC with current FC on sensitivity of ICTAD formula**

PROJECT	When X = 0.966		When X = 0.757	
	Difference	% of Over Estimate	Difference	% of Over Estimate
Model	Rs. 30,752.55	20.62 %	-Rs. 8,172.60	-5.48 %
1	Rs. 521,671.60	29.03 %	Rs. 19,974.63	1.11 %
2	Rs. 38,591.58	26.68 %	-Rs. 1,055.05	-0.73 %
3	Rs. 104,368.60	69.75 %	Rs. 49,412.87	33.02 %
4	Rs. 682,060.44	79.63 %	Rs. 349,176.57	40.77 %



**Figure 9 Comparison of modified FC with current FC on sensitivity of ICTAD formula**

Comparing over-estimates resulted from the current ICTAD FC and the modified FC, it is clear that in all selected projects including model project, the over-estimates of PA drastically reduced due to the application of modified FC. Therefore, the use of this modified FC instead of the current FC may increase the sensitivity of the ICTAD price adjustment formula reducing the large over-estimations leading to more client/contractor satisfaction in the construction industry.

## 6 CONCLUSION

The aim of this paper is to evaluate on the sensitivity of the ICTAD price fluctuation formula method for the successful construction projects. To achieve this aim, three

objectives are set as to find the relationship between ICTAD price adjustments & true PAs, to estimate the accuracy of the ICTAD formula method for the PAs and to propose a modification to increase the accuracy of ICTAD formula through the statistical analysis. Following three chapters explain the conclusion on the findings of this study with relevant to the three objectives.

- (a) The data analysis on both model project and selected projects indicated that the ICTAD price adjustment formula depends on five parameters namely input percentage ( $P_x$ ), price indices ( $I_x$ ), cost adjustment factor ( $K$ ), rest adjustment factor ( $R$ ) and valuation assessed ( $V - V_{na}$ ). Also, the two basic assumptions of ICTAD formula, i.e. uniformly distributed  $P_x$  and 80-20 concept are found to be inaccurate. Furthermore, the fixed values of CAF and RAF cannot be used for every project due to its variability. Therefore, the data analysis revealed that these parameters have some shortcomings and combined effect of these issues result in a large over-estimation on the PA computed using current ICTAD formula compared to the true price fluctuation. The shortcomings which can be observed in the ICTAD fluctuation calculations cannot be seen in the conventional price fluctuation calculations due to the straightforwardness of the concept based on it. This can be explained as follows.
  - (i) The true PA based on the quantity of inputs which are used in the particular month and therefore if an input not used in that bill month, then the PA due to that input gets zero even with a positive or negative change of cost. Hence, in this method the over-estimates resulted due to the non-uniformly distributed input percentages are prevented.
  - (ii) There are no factors used for this method and PA for inputs can be directly calculated.
  - (iii) The true PA is based on the change of cost, but not the valuation assessed. Therefore, there are no effects from items which are not liable to the PA.
- (b) The sensitivity analysis on selected projects with seven numbers of different price fluctuation scenarios indicated that in majority of cases ICTAD price adjustment was greater than the true PA. Also, when the amount of PA increases, the difference between formula adjustment and true adjustment increases. Therefore, in this analysis, the accuracy of ICTAD formula is challenged under the different fluctuation scenarios. The accuracy of the formula decreases due to the effect of valuation assessed. The valuation assessed consists of the total work done within the valuation period and this work done is contributed by inputs liable and unliable to price fluctuation. This will lead to a large value of ICTAD price adjustment with a small input value factors. Therefore, the sensitivity analysis justified that the use of valuation assessed to compute the PA in the ICTAD formula is not sensitive to the true price fluctuation.
- (c) The statistical analysis on the selected projects with their fluctuation scenarios proved that the factors related to the ICTAD price adjustment must be modified to increase the sensitivity of the ICTAD price adjustment relative to the true PA.

However, individual modifications for input percentages, price indices and valuation assessed are impractical since the relationships of those factors with the PA considerably varied from project to project and fluctuation scenario to fluctuation scenario. Therefore, the combined effect of these factors is considered and from the data and sensitivity analysis it is found that the modification of FC in the current ICTAD formula can address above mentioned issues. The FC directly depends on the K and R, but it is reasonable to take R as 10% since the statistical analysis considered only the building construction projects. The variation of FC with different K values takes a form of simple parabola, but this variation can be fitted to the linear variation. The computed new FC according to the linear regression analysis and the weighted average basis has the flexibility to close the ICTAD price adjustment to the true PA.

This study was only limited to building construction projects and the selected number of samples are also limited to four. In order to arrive at a general conclusion resulting in a close representation, it is advisable to analyze at least 30 projects of varying nature. These two points are the limitations of this study. However, selection of seven fluctuation scenarios for four numbers of projects gave approximately the equivalent effect of 30 projects. The modified FC for the ICTAD formula which is computed at the end of this study has considered the effect of variation of input percentages, price indices, CAF, RAF and valuation assessed with a more logical way.

## REFERENCES

1. Abeyssekara, WVKM 1997, Construction contracts and claims-Project Report, OUSL.
2. Association of South African quantity surveyors 2013, Contract price adjustment provisions, Midrand, ASAQS.
3. Bent, JA & Humphreys, KK 1996, Effective project management through applied cost and schedule control, CRC Press, Florida.
4. Bhatnagar, V 2014, Data mining and analysis in the engineering field, IGI global, Hershey.
5. CPWD 2007, CPWD works manual, New Delhi, CPWD.
6. Chaphalkar, NB & Sandbhor, SS 2012, Wholesale price index and its effect on price escalation of materials for Indian construction industry, Maharashtra, IJERT.
7. Construction industry council 2011, Guidelines on contract price fluctuation system, Hong Kong, CIC.
8. Dimov, I, Fidanova, S & Lirkov I 2015, Numerical methods and applications, Springer, Heidelberg.
9. FIDIC 2005, Conditions of contract for construction: for building and engineering works designed by the employer, Geneva, FIDIC.
10. Gwet, KL 2010, The practical guide to statistics:basic concepts, methods and meaning application with MS excel, R and openoffice calc, Advanced analytics, Gaithersburg.
11. ICTAD 2008, ICTAD formula method for adjustments to contract price due to fluctuation in prices, Colombo, ICTAD.
12. ICTAD 2007, Standard bidding document: procurement of works, Colombo, ICTAD.
13. ICTAD 2013, ICTAD statistical bulletin, Colombo, ICTAD.
14. JCT 2011, Formula rules 2011, London, JCT.
15. Lawrence, KD, Klimberg, RK & Lawrence, SM 2009, Fundamentals of forecasting using excel, Industrial Press, New York.
16. Mel, JD 2013, Basic concepts and logical approach of ICTAD formula, Colombo, ICTAD.

17. Montgomery, DC, Peck, EA & Vining, GG 2012, Introduction to linear regression analysis, John Wiley & Sons, New Jersey.
18. PEC 2005, Standard guidelines and formula for price adjustment, Islamabad, PEC.
19. Samaraweera, D 2013, Application of the formula, Colombo, ICTAD.
20. Taylor, JK & Cihon, C 2004, Statistical techniques for data analysis, CRC Press, Florida.