A RATIONAL METHOD FOR THE TREATMENT OF ESCALATION IN CONSTRUCTION COSTS

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By

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ABSTRACT

Escalation of construction costs constitute a substantial part of the total costs of many construction projects. Drastically changing escalation rates can have adverse effects on the success of such projects. The main objective of this thesis is to examines construction cost escalation and recommend suitable analytical techniques to quantify its impact.

The causes of escalation are examined. Many of these causes are found to be unpredictable by their very nature. As such the main effect of escalation is to cause risk and uncertainty regarding a project's cost.

Methods of assessing the amounts allowed in construction contracts to cover escalation are reviewed. It is established that these amounts can best be assessed using the concept of expected utility value. Based on this concept, financially stable contractors will include larger monetary sums to cover cost escalation risk than a large owner, like government, would be willing to pay for the same risk.

Forecasts of the amount of escalation are required for budgetary and bidding purposes. These forecasts may be obtained by forecasting cost indices that measure the escalation rate and applying this rate to the estimated cash flow. Methods of forecasting construction cost indices using time series analysis are examined. The theories underlying these methods are outlined. The application of these methods using a computer software package is illustrated.

Methods of using the forecasted indices are reviewed. Parsimony is found to dictate use of cost flow models based on polynomial regression. The use of such cost flow models is demonstrated.

None of the available forecast.ng techniques are found to provide a panacea for obviating the effect of construction cost escalation. The effect of escalation can be minimized by carefully allocating the risk of escalation using escalation clauses. Guidelines for the use of escalation clauses are stipulated. It is concluded that except for than in short construction projects to be built under stable conditions, the risk of escalation should be borne by the owner.

Various types of escalation clauses are reviewed. Use of escalation clauses incorporating a formula based on indices is recommended. It is also recommended that regularly published indices should be maintained to provide for construction cost escalation and for use in other estimating situations.

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LIST OF SYMBOLS AND ABBREVIATIONS

a	parameter (constant) estimated by regression analysis
a_i	weight of commodity i
AIC	Akaike Information Criterion
AMI	Architectural Materials Index
AMI[-12]	the AMI lagged 12 months
AR	autoregressive
ARIMA	Autoregressive Integrated Moving Average
ASCE	American Society of Civil Engineers
b	parameter (constant) estimated by regression analysis
$B(r,s)$	beta function of r and s
BCI	Building Cost Index
BFS	Business Forecast Systems, Inc.
BIC	Bayesian Information Criterion
BSC	Breakthrough Software Corporation
C	parameter to be estimated
c	parameter (constant) estimated by regression analysis
C_{ai}	cost index of commodity i at time of valuation
C_{oi}	cost index of commodity i at date of tender
CBLR	Commercial Bank Lending Rate index
CBMPI	Construction Building Materials Price Index
CCI	Construction Cost Index
CPM	Critical Path Method
d	parameter (constant) estimated by regression analysis
d	degree of differencing
DPWT	Department of Public Works and Transportation
E_T	total project escalation cost
e_t	error term at time t
E_i	escalation cost in time interval i
EMV	expected monetary value
ENR	Engineering News Record
EUV	expected utility value
F_i	escalation factor for time interval i
$f_Y(y)$	probability density function of Y
I	integration
I_t	price index at time t
K	parameter to be estimated
L_t	smoothed level at time t

MA	moving average
M.A.P.E.	mean absolute percentage error
n	number of periods in seasonal cycle
MC	Microsoft Corporation
NEDO	National Economic Development Office
p	order of autoregressive operation
P(A)	probability of occurrence of possible dollar profit A
PERT	Programme Evaluation and Review Technique
P_i	unescalated expenditure in time interval i
PS	Primavera Systems, Inc.
$(P_{to})_i$	ratio of prices of commodity i between the time base period 0 and period t
$P(x_i)$	probability of occurrence of possible future outcome i
PWBII	Prefabricated Wooden Building Industry Index
PWBII[-1]	the PWBII lagged 1 month
q	order of moving average operation
r	positive number and parameter of beta distribution
s	positive number and parameters of beta distribution
S	contract sum
S_t	smoothed seasonal index at time t
S&PMPI	Sawmill and Planing Mill Products Index
TSC	Timberline Software Corporation
T_t	smoothed trend at time t
U(A)	utility of possible dollar profit A
$U(x_i)$	utility value of possible future outcome with monetary value x_i
UWRI	Union Wage Rate Index
UWRI[-5]	the UWRI lagged 5 months
W_i	weight or relative importance of commodity i
x	percentage of total time
x_i	cost of possible future outcome i
y	percentage of total cost
Y	cumulative monthly value of work executed
Y_t	observed value of time series at time t
$\hat{Y}_{t(m)}$	forecast for lead time m from time t
$\hat{Y}_t$	forecasted value of time series at time t
Y_{t-i}	observed value of time series at time $t-i$
Y_{dt}	value of dependent variable at time t
X_{it}	observed value of the i^{th} explanatory variable at time t
α	level smoothing parameter
β_i	coefficient of X_i

δ	seasonal index smoothing parameter
δ_r	adjustment due to escalation
Δ	total unadjusted value of work executed
γ	trend smoothing parameter
$\Gamma(r)$	gamma function of r
$\Gamma(s)$	gamma function of s
ϕ_i	weighting coefficient of the i^{th} previous period
θ_q	weighting coefficient of the q^{th} previous period
$\hat{\mu}_Y$	average of completed project's cost
$\hat{\sigma}_Y^2$	variance of completed project's cost

GLOSSARY

AIC (Akaike Information Criterion) The AIC is a figure of merit used in determining Box-Jenkins models. Based on empirical research, the model with the lowest AIC will generally be the most accurate (Goodrich and Stellewagen, 1987)

ARIMA An ARIMA process is an autoregressive-integrated moving average process. This wide class of processes provides a range of models, stationary and non-stationary, that adequately represent many of the time series met in practice (Box and Jenkins, 1976).

Autocorrelation The correlation of a variable and itself a fixed number of periods later.

Autoregressive An autoregressive model is a stochastic model in which the current value of a process is expressed as a finite, linear aggregate of previous values of the process and a shock term.

BIC (Bayes Information Criterion) The BIC is a figure of merit used in determining Box-Jenkins models. Based on empirical research, the model with the lowest BIC will generally be the most accurate (Goodrich and Stellewagen, 1987).

Differencing Differencing is the transformation of a time series involving the replacement of every value of the series by its difference from the previous value.

Escalation Escalation in construction costs is the increase in the costs of any of the construction elements required for original contract works occurring during construction.

Expected monetary value The expected monetary value is a measure of value that can be used in situations where there are various possible future outcomes each with an attendant amount of loss or gain. The expected monetary value is the sum of the product of the cost of each possible future outcome with its probability.

Expected utility value The expected utility value is a measure of value that can be used in situations where there are various possible future outcomes each with an attendant amount of loss or gain. The expected utility value is the sum of the product of the utility value of each possible future outcome with its probability. The utility value of each possible future outcome is obtained from a utility function developed specifically for the decision making party to represent the parties preference for varying monetary amounts over the entire range of possible future outcomes.

Homoscedasticity A time series is termed homoscedastic if its variance and covariance do not change with time.

Integration A time series is integrated with degree d if d is the minimum degree of differencing that renders the time series stationary.

Lag Lag is the difference in time units of a series value and a previous series value.

MAPE (Mean Absolute Percentage Error) MAPE is a measure of the accuracy of forecasts made of future values of a time series. To obtain the MAPE, the difference between each forecasted value of a time series and the actual observed values is first calculated. The MAPE is then computed as the average of the magnitudes of these differences when these differences are expressed as a percentage of the actual observed values.

Multivariate A multivariate method is a method involving more than one variable at a time.

Risk The term risk, when used in the context of construction cost escalation, means the possibility of financial loss arising from the execution of a construction contract.

Robust A robust statistical method is a statistical method which is insensitive to moderate deviations from underlying statistical assumptions.

Univariate A univariate method is a method involving only one variable at a time.

Chapter 1

INTRODUCTION

1.1 Background

Websters dictionary defines to escalate as :"to gradually increase ... ; to raise and go up ..." Escalation in construction costs is the increase in the costs of any of the construction elements required for original contract works occurring during construction. The amount included in any construction cost estimate or construction cost breakdown to account for escalation in construction costs is an important component of total construction costs. This amount deserves thorough consideration and rational treatment throughout the entire construction process.

A substantial part of the cost of many construction projects is attributable to escalation in construction costs. For example, in a feasibility study (prepared in February 1974) of delivering power from Gull Island Hydro-electric site to Newfoundland using land type cables in tunnel, the amount of escalation to January 1979 was estimated at $13,420,000 as shown in Table 1.1 (Teshmont, 1974). This was almost equal to the of cost of cable procurement and installation estimated to be $14,905,000 and was a major component of the total construction cost estimate.

Table 1.1: Cost estimate for land type cables in tunnel (from Teshmont, 1974)

Cable Procurement and Installation	$ 14,905,000
Tunnel Construction	37,725,000
Logistics and Construction Support	13,890,000
Subtotal	66,520,000
Engineering and Owners Administration	5,440,000
Contingency	7,370,000
Total 1974 Cost	$ 79,330,000
Escalation to January 1, 1979	13,420,000
I.D.C April 1974 to January 1979	17,980,000
TOTAL CAPITAL COST	$ 110,730,000

The financial success of construction projects can be uncertain and at risk due to the possibility of drastically changing escalation rates during construction. At the beginning of any given project, there can be a number of different possible future escalation rates. Use of an erroneous escalation rate when estimating construction costs can have adverse effects on economic decision making for both owner and contractor. As an example, Figure 1.1 illustrates the impact of changing escalation rates on a hypothetical construction project with an unescalated cost of $40,000,000. The cost flow profile of the project is expected to form the predetermined S-shaped curves shown in Figure 1.1 (Thamm, 1980). The project is to be constructed over a period of 3 years starting 3 months from the date of tender. Figure 1.1 indicates that if an annual escalation rate of 10% is experienced during construction instead of a prior estimated rate of 3%, a loss of $ 6,000,000 would be incurred. The party that bears the escalation risk can be devastated by this loss.

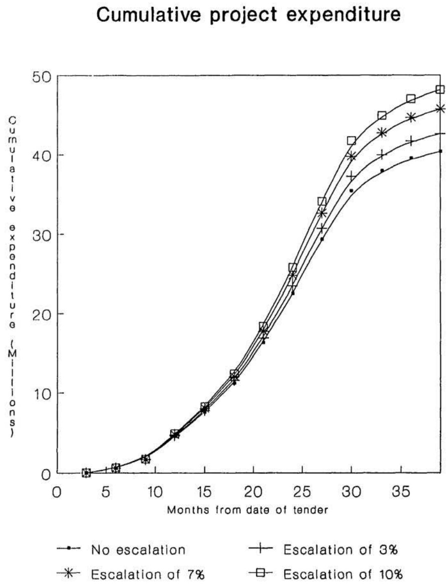


Figure 1.1: Impact of various annual escalation rates on construction costs

Escalation risk is shared by the use of escalation clauses in contract documents. There are conflicting opinions on the use of escalation clauses in fixed price contracts (ENR, 1980). In North America, fixed or unit price contracts are the standard in construction, and most construction contracts have no cost fluctuation or escalation clauses (Fellows, 1984). In Newfoundland, all contracts handled by the Department of Public Works and Transportation do not have escalation clauses (Brophey, 1990). Fellows (1984) states that in other parts of the world, especially in the United Kingdom, building contracts offer a continuum of possible escalation reimbursement methods, and there is a general trend towards using formula escalation for major construction contracts. There are no hard and fast rules as to when escalation clauses should be used, although it is known that in some situations the use of these clauses to share the risk of escalation is required .

1.2 Expected benefit and objectives

This thesis aims at examining construction cost escalation covering the available analytical techniques to quantify its impact. The expected benefit is the resultant treatise that can be of immediate use in the construction industry. To produce a document covering the available analytical techniques to quantify the impact of escalation, the objectives of this research can be summarized as follows:

1. To examine the causes of escalation and its effect on the various types of contracts.
2. To recommend a mathematical model to use in forecasting escalation.
3. To provide guidelines for the use of escalation clauses in construction contracts.
4. To recommend a rational method for computing escalation costs when escalation clauses are used.

1.3 Methodology

The examination of construction cost escalation covering the available analytical techniques to quantify its impact is acheived by following the steps shown in Figure 1.2 and discussed below.

The causes of escalation and its effect on various types of contracts are first examined from a review of available literature. From this review, recommendations of construction contracts provisions that minimize the effect of escalation are made.

A forecast of the amount of escalation in construction costs is required for budgetary and bidding purposes. Various forecasting methods available and in use in econometrics, business and construction are reviewed. From the review, recommendations are made of those methods which would be appropriate for forecasting the amount of escalation in construction cost.

To forecast the amount of escalation in the costs of any construction project, it is necessary to forecast the escalation rate and apply this rate to the estimated expenditure cash flow. The escalation rate is measured by means of cost indices. Examples are given for the use of recommended forecasting methods in forecasting a selected construction cost index obtained from Statistics Canada. The examples include a discussion of the usefulness and limitations of the forecasting methods.

Methods of applying the forecasted escalation rate to a construction projects cash flow are examined. A model is recommended for estimating a construction projects cash flow for use in forecasting the amount of escalation in construction costs.

Finally, various conflicting attitudes to sharing the risk of cost escalation

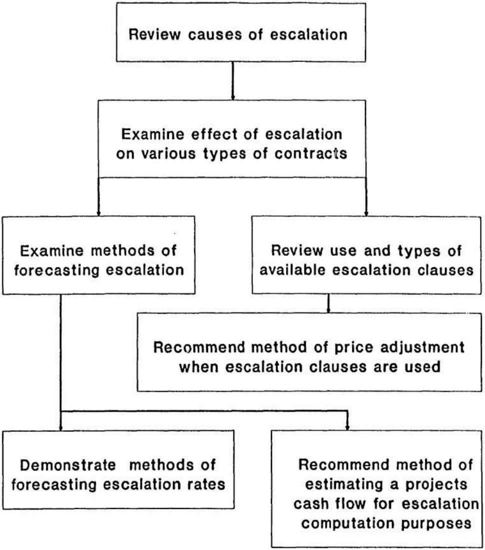


Figure 1.2: Flow diagram of steps to be taken in examining construction cost escalation

are examined. This is done in order to establish guidelines as to the circumstances that should exist before escalation clauses are incorporated in construction contracts. The examination includes a review of methods of price adjustment used in fluctuation or escalation clauses and a recommendation of a method for price adjustment to compensate for escalation.

1.4 Scope

There are many fields in construction, and although there are no clear cut lines separating the various fields, they can be roughly divided into residential, building-commercial, industrial, highway-heavy and speciality (Peurifoy and Ledbetter, 1985). Necessary inputs and construction methods differ from field to field. Variations in design within any one given field necessitate different inputs in differing proportions. Consequently, it is not possible to specify a model for estimating a contract's cash flow for escalation purposes that is directly applicable not only to all fields but even to all designs in a given field of construction. Nonetheless, the basic principles that apply to any model used in one field should apply to other fields. This thesis will quantitatively apply a recommended model to selected examples in the building-commercial field.

There exists a plethora of forecasting methods in use in various disciplines some of which are very esoteric. As such, it is not possible to review all existing forecasting methods and analyze the application of all possible appropriate forecasting methods to construction. Most forecasting methods, however, are modifications of a number of commonly applied forecasting methods or families of forecasting models. This thesis will examine the usefulness and limitations of only the commonly applied forecasting methods or families of forecasting models.

A lot of data which would have been useful in this research is proprietary and cannot be accessed. Case study data will therefore be used to demonstrate the application of suggested or recommended methods. While the use of case study data is helpful, in some cases it lacks the breadth required to make generalizations applicable to the entire construction industry. The methodologies discussed in this thesis are, however, applicable to all escalation scenarios.

One method of reducing the amount of escalation is the use of prepayments or mobilization payments. Prepayments, however, result in an increase in the cost of interest during construction. The balancing of the amount of prepayments necessary to minimize the combined cost of escalation and interest during construction is not within the scope of this research and will not be addressed herein.

1.5 Thesis organization

This thesis is divided into seven chapters. The first chapter, which for the most part is already presented, introduces the research, outlines the research objectives, and presents the scope, methodology, and organization of the thesis. The next chapter, Chapter 2, outlines the causes of escalation, discusses the effect of escalation on various types of contracts, and recommends means of measuring the effect of escalation for contractual risk allocation purposes. Chapter 3 examines the analytical techniques available to forecast the rate of escalation. Chapter 4 discusses the application of the forecasted rate of escalation to the estimated cash flow expenditure of a given construction project and evaluates methods of forecasting a project's cash flow expenditure for escalation computation purposes. The use of escalation clauses is discussed in Chapter 5 in which a method of price adjustment when escalation clauses are used is recommended. Chapter 6 specifically addresses the use of cost indices in quantifying escalation both for price adjustment and forecasting purposes. Finally, summary and conclusions are given in Chapter 7.

Chapter 2

CAUSES AND EFFECT OF ESCALATION

In order to recommend alternate methods for use in the construction industry to treat escalation in construction costs, one must first understand its causes. This chapter outlines the causes of escalation, discusses the effect of escalation on various types of contracts and recommends means of measuring the effect of escalation for contractual risk allocation purposes.

2.1 Causes of escalation

The causes of escalation differ from project to project because of the diversity of required construction cost elements and differing conditions and methods of construction. Nonetheless, the principle causes of escalation in most construction projects are as depicted in Figure 2.1 and outlined below:

1. Inflation: The Economics Dictionary (Moffat, 1976) states that there are many definitions of inflation, but for most practical purposes inflation can be considered as the " decrease in the purchasing power of the nations money." The cost of construction elements increases with inflation and thus inflation causes construction cost escalation.

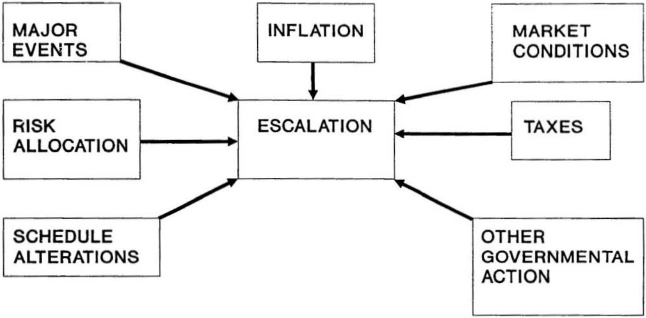


Figure 2.1: Principle causes of escalation

2. Market conditions: Shortages of any given material or labour and any increase in the level of construction activities causing increased demand of construction elements will cause escalation of construction costs.
3. Taxes: Any taxes or duties adjusted or imposed on construction elements during the period of construction will have a direct impact on the cost of construction.
4. Other Governmental action: Government requirements, for example those which relate to safety, labour, or environmental standards, may be altered during the period of construction and lead to cost increases.

   Quasi-government bodies like the Organization of Petroleum Exporting Countries dictate prices which may change during construction. Governmental action is not limited to a given contractor or direct supplier but to any necessary string of suppliers. Any party handling a construction element from its original location or condition can be affected. This would ultimately affect the construction price (Padrnos 1981).
5. Schedule alterations: Schedule extension may be necessary if any required construction elements are delayed for unforeseen reasons. Schedule extension can be caused by a multitude of other factors such as change orders, abnormal weather conditions, strikes, and poor management. Any extension of contract schedule ultimately increases construction costs.
6. Allocation of risk: Levitt et al (1980) say that allocation of uncontrollable risk by contract to the contractor causes escalation. This is mainly due to "resorting to litigation or arbitration for any possible type of dispute, whether warranted or not" resulting in costly delays and legal action.
7. Major events : Major national and international events like war can have an impact on construction and cause cost escalation.

The above outlined causes of escalation are not exhaustive. Many other factors can cause escalation of construction costs. Many of the causes of escalation are by their very nature unpredictable. For instance, the occurrence of major events like war or the actions of quasi-government bodies. As a result, escalation contributes to the uncertainty in the final cost of a construction project at any time before the project is complete.

2.2 Effect of escalation

The main effect of escalation is that it introduces risk and uncertainty regarding a project's cost before and during a project's execution (Warzawski, 1982a). Hardie (1981) states that "the placement of financial risk is the deciding factor in selection of the type of contract for a particular project." Indeed, the impact of the risk caused by escalation of construction costs on the parties to any contract varies according to the type of contract.

In order to assess the effect of escalation, it is necessary to classify contracts according to the manner in which responsibility for escalation costs is incorporated into contracts. As Oyamada and Yokoyama (1986) put it, "project risk is incorporated into the contract conditions or summed up into the estimates value as a contingency." Ibbs et al (1987) reiterate "contracts are defined as some derivative of either cost reimbursable or fixed price contracts." In discussing the effect of escalation, contracts will herein be classified as either fixed price contracts or contracts with a compensation or escalation clause.

2.2.1 Effect in fixed price contracts

In fixed price contracts, whether lump sum or unit price, escalation can cause the contractor to "go into the red" (Oyamada and Yokoyama, 1986). The risk borne by the contractor manifests itself primarily in the amount of money included in the contract sum to cover escalation. Unless the contractor included a sufficient amount to cover escalation in his bid, the number of contractual disputes will significantly increase as the contractor seeks reason for claims (Ibbs and Ashley, 1987). Thus, as Warszawski (1982a) states, "the owner must accept an offer of a prudent contractor with a high risk factor reflected in price or cope with a contractor who underestimated costs and later tries to recuperate his losses through constant claims and poor work quality."

2.2.2 Effect in contracts with a compensation or escalation clause

In contracts with a compensation or escalation clause the effect of escalation to the contractor is significantly reduced or non-existent. Administrative costs and uncertainty to the owner, however, increase. Such contracts require carefully structured compensation or escalation clauses. Claims by the contractor for payment to reimburse escalation of costs have to be verified during execution of the contract. This increases administrative costs to the owner (Erickson et al, 1978). The owner has to include an amount in his budget, over and above the contract sum, to cover escalation. Levitt et al (1980) state:

"increased risk associated with final contract price... will reduce the projects worth to the owner... some public owners find it very difficult (for funding and political reasons) to accept uncertainty in contract price."

2.3 Construction cost risk

The effect of escalation as determined above is risk, and the value of the amount paid by the owner for escalation depends on the attitudes towards risk of the various parties to any contract. In order to recommend methods to minimize the amount paid by the owner for escalation, it is therefore necessary to examine the concept of risk due to cost escalation.

The term, "risk" herein implies the possibility of financial loss or gain arising from the execution of a construction contract (Carr, 1977). The party that bears the risk is largely determined by the terms of the contract. The manner in which the risk is shared or borne will significantly affect the contract sum and the final construction costs (Levitt et al, 1980). The owner ultimately pays the price of construction including inherent risks, since, even in fixed price contracts, the contractor's price includes an amount to cover escalation costs (ASCE, 1979). The amount paid, however, may be optimized by judicious allocation of escalation risk. To do this, it is essential to measure the value the contractor or the owner associates with varying amounts of possible future escalation costs, each with some estimated probability of occurrence.

2.4 Measures of value embodying risk

There are two measures of value that can be used in situations where there are various possible future outcomes, each with an attendant amount of loss or gain namely:

1. Expected monetary value
2. Expected utility value.

2.4.1 Expected monetary value

The expected monetary value is the sum of the product of the cost of each possible future outcome with its probability. The expected monetary value can be mathematically represented as (Carr 1977):

$$EMV = \sum_{all\ i} x_i P(x_i) \tag{2.1}$$

Where:

$EMV =$ Expected monetary value.

x_i = Cost of possible future outcome i.

$P(x_i)$ = Probability of occurrence of possible future outcome i.

2.4.2 Expected utility value

The concept of expected utility value was developed to take into account the fact that the value an individual places on a given monetary amount depends on the particular circumstances of the individual. The expected utility value can be mathematically represented as (Carr 1977):

$$EUV = \sum_{all\ i} U(x_i)P(x_i) \tag{2.2}$$

Where:

EUV = Expected utility value.

$U(x_i)$ = Utility value of possible future outcome with monetary value x_i.

$P(x_i)$ = Probability of occurrence of possible future outcome i.

The utility value of each possible future outcome is obtained from a utility function which has been developed specifically for the party making the decision. This utility function represents the parties preference for various monetary amounts over the entire range of possible future outcomes.

2.5 Choice of measure of value

The appropriate measure of value to use in optimizing risk allocation is expected utility value rather than expected monetary value (Erickson et al., 1978). This is because use of the expected monetary value presupposes indifference to the magnitudes of the amounts due to the various possible future outcomes as long as the expected monetary value is the same. For instance, a contractor may be indifferent to a 50–50 chance of loss or gain of say $1,000, but may not be indifferent when the magnitude of loss or gain is say, $1,000,000 even though the expected monetary value in both cases is zero. Furthermore, use of the expected monetary value is based on the assumption that the risky process will be repeated with a sufficiently high frequency such that varying profits and losses in the short run will average out to the expected monetary value in the long run. This is not the case for risks involved in escalation of construction costs. The averaging out in the long run will not occur if the amount of loss is so great that a given party goes out of business. In this case, the assumption of frequency, on which the use of the expected monetary value is based, does not hold. The concept of expected utility value, rather than the concept of expected monetary value, will therefore be used in optimizing risk allocation.

2.6 Establishing a party's utility function

To use the expected utility value concept it is necessary to develop the parties utility function. A party's utility function can be developed by interviewing the party. This process begins by arbitrarily assigning utility values on some arbitrary scale to any two monetary sums subject to the condition that the larger the monetary sum the larger the utility. After establishing these two points, the utility value for all other sums can be uniquely determined.

The manner of determination is demonstrated by the following example (Erikson and O'Connor, 1979). Let A and C represent two possible dollar profits with probabilities of occurrence of P(A) and P(C). Let U(A) and U(C) represent the utilities of A and C respectively. If the party is indifferent between a definite profit of B and the chance of getting profits A and C, the utility of B can be determined as follows:

$$EUV = U(A) * P(A) + U(C) * P(C) = U(B) * P(B)$$

where: $P(B) = 1$

Solving for $U(B)$ provides a third point on the individuals utility function. This procedure can be repeated to determine as many points as desired to define the individuals utility function. The individuals risk preference is classified by the form of the resultant utility function.

2.7 Classification of individual risk preferences

2.7.1 General classification

The expected utility value of a given risk situation to a given party depends on the parties risk preferences. For any set of conditions, Erickson et al (1978) identify three distinct classes of individual risk preferences namely:

1. Risk averse: Where a party places a higher value to the risk than the expected monetary value.
2. Risk neutral: Where a party places a value to the risk equal to the expected monetary value.
3. Risk taker or gambler: Where a party places a lower value to the risk than the expected monetary value.

The characteristic forms of the utility functions for the above classes of risk preference are depicted in Table 2.1. In Table 2.1, the profit in dollars is plotted on the x-axis against the expected utility value measured on an arbitrary scale called utiles on the y-axis. Increasing utiles with profit

Table 2.1: Classification of individual risk preference (from Erikson and O'Connor,1979) Approved for public release: distribution unlimited by Construction Engineering Research Laboratory (CERL)

TYPE	RISK AVERSE	RISK NEUTRAL	RISK TAKER
UTILITY FUNCTION	UTILITY +Utiles +$ PROFIT	UTILITY +Utiles +$ PROFIT	UTILITY +Utiles +$ PROFIT
FIRST DERIVATIVE	$\frac{dU}{dP} > 0$ PREFER MORE MONEY TO LESS MONEY	$\frac{dU}{dP} > 0$ PREFER MORE MONEY TO LESS MONEY	$\frac{dU}{dP} > 0$ PREFER MORE MONEY TO LESS MONEY
SECOND DERIVATIVE	$\frac{d^2U}{dP^2} < 0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT LESS HIGHLY THAN THE PREVIOUS DOLLAR OF PROFIT	$\frac{d^2U}{dP^2} = 0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT THE SAME AS THE PREVIOUS DOLLAR OF PROFIT	$\frac{d^2U}{dP^2} > 0$ SUBJECTIVELY VALUE THE NEXT DOLLAR OF PROFIT MORE HIGHLY THAN THE PREVIOUS DOLLAR OF PROFIT
INTERPRETATION	WILL NOT WILLINGLY ASSUME RISK EXPOSURE UNLESS THE COMPENSATION EXCEEDS THE EXPECTED MONETARY VALUE OF THE RISK	WILL ASSUME RISK EXPOSURE IF THE COMPENSATION IS NOT LESS THAN THE EXPECTED MONETARY VALUE OF THE RISK	MAY BE WILLING TO ASSUME RISK EXPOSURE EVEN IF THE COMPENSATION IS LESS THAN THE EXPECTED MONETARY VALUE OF THE RISK

depicted for all three broad classifications (all classifications have positive first derivatives of utiles with profit) indicate that all individuals prefer more profit to less. The second derivative indicates the subjective marginal utility an individual places on additional profit. The interpretation of these curves with regards to risk exposure is given in Table 2.1.

As Willenbrock (1973) asserts, the utility functions depicted are cardinal rather than ordinal. It therefore cannot be concluded that an individual prefers a dollar amount B six times as much as an amount A simply because the utilities of A and B as obtained from the individual's utility function are 10 and 60 respectively. The utility scale is arbitrary and another scale could just as well have been used for which the utility of A is 10 and that of B is 600. Nonetheless, the relative magnitudes of differences between utility numbers are meaningful in that they do not change under linear transformation. Because of this characteristic, the general shape of the utility function is not dependant on the origin and scale chosen.

2.7.2 Classification of contractors risk preference

The contractors risk preferences will depend on his financial position. Financially stable contractors are typically risk averse because as Warszawski (1982b) attests " the assets of most contractors are low in comparison with their contract volumes, and they may be highly vulnerable to losses."

When the contractor is financially insecure he is already at risk of being out of business. Therefore, additional contract risk may not carry as much weight to the contractor as the possibility of financial gain which a financially insecure contractor may desperately require. The contractor thus takes on a more gambling or risk taking attitude (Carr, 1977). Willenbrock (1973) aptly described a risk taking contractor as

> " a gambler, a player of long shots, a man who feels that even a large loss could not make things much worse than they are now whereas a large profit could very substantially improve his whole situation. This contractor values the small chance at large gains very highly."

When drafting contracts to be signed by a contractor yet to be determined it is most appropriate to assume that the contractor will be risk averse therefore allowing for optimal risk allocation. This is because financially stable contractors are more likely to be risk averse and contracts are best made with financially secure contractors.

2.7.3 Classification of owners risk preference

To the owner, the risk involved in construction costs is only a portion of the total risk in projects costs. This is because the owners view of the total project costs include the cost of the various components in the projects life cycle (such as operation and maintenance costs, expected revenue and salvage value), each with their attendant risk. In addition, some owners like government, are large and are engaged in a number of construction projects. Unlike the contractor, the owners assets are likely to be high in comparison to the contract costs, and thus the owner will not be as vulnerable as the contractor to losses due to variation in contract price. Owners are therefore more likely to be risk neutral though each individual owner's risk preference should be examined. In general, as Carr (1977) points out," the owners perception of risk ... is broader than the contractors."

2.8 Risk allocation based on utility value considerations

From a purely expected utility point of view, it can therefore be said that a risk averse contractor will include in his price a higher amount than the expected monetary value and thus a higher amount than a risk neutral owner would be willing to pay for the same risk (Erickson et al., 1978). As Carr (1977) states:" it will usually pay the owner to accept as much as possible of any risk."

In general, a large owner like government will pay less for escalation if he assumes the risk of cost escalation in fixed price contracts. This is because the amount a contractor includes to cover cost escalation in his bid will be more than the value at which the large owner assesses the risk. An example of how the utility value theory can be used to model the cost effects of allocation of escalation risk is given in Appendix A.

The determination of the exact form of a party's utility function can be quite difficult in practice and depending on the format of the questionaire may vary from interviewer to interviewer. However, the exact form of the utility function is not required in order to decide how to allocate construction escalation risk. What needs to be determined is whether a given party is risk averse, risk neutral, or a risk taker and this does not vary with interviewer or format of questionaire in normal circumstances. If the contactor is risk averse and the owner is risk neutral or a risk taker then the risk of cost escalation would best be borne by the owner.

The expected utility value of the amount included in a bid is, however, not the only factor to consider in making a decision on whether or not to use escalation clauses to assign the risk of cost escalation to the owner. Other considerations are discussed in Chapter 5.

Chapter 3

FORECASTING THE RATE OF COST ESCALATION

3.1 Introduction

It is necessary, for budgetary and bidding purposes, to forecast the amount in monetary terms of escalation costs that will be incurred during the execution of a construction project. To forecast the amount of cost escalation, one can forecast an applicable escalation rate and apply this rate to the estimated cash flow. Forecasting the applicable escalation rate can be achieved by forecasting the future value of an appropriate cost index. Cost indices are indicators of the amount of cost escalation. Indices describe how the cost of a particular construction unit changes with time. The formulation and structure of appropriate cost indexes are discussed in Chapter 6. Cost indices are time series because they are generally produced at regular time intervals. Methods for analyzing and forecasting time series can therefore be used to forecast the rate of escalation of a given construction project.

A number of methods are available for forecasting time series. Many of these methods require a substantial degree of mathematical dexterity and can be time consuming. In the past, the parties to a contract were often advised to hire a consultant to apply these techniques (Stevenson 1984). The current availability of user friendly computer forecasting software packages, such as FORECAST PRO (BFS, 1988), have now reduced the amount of mathematical manipulation necessary for a practitioner. The key requirements in applying the various forecasting methods using these packages are the ability to interpret the computer output and an understanding of the limitations of the techniques used.

This chapter examines the analytical techniques available to forecast the rate of escalation of construction costs by forecasting the values of an appropriate cost index. A brief outline of the theory underlying the various forecasting methods applicable to construction cost forecasting is given. Forecasting the values of a cost index published by Statistics Canada using FORECAST PRO is used as an example of the application of each of the applicable forecasting methods. From these examples, and from the outline of the underlying theory, the benefits and limitations of each method are discussed and a general strategy for choosing between various methods is given. Finally, the usefulness of the various forecasting methods to the owner and contractor of a given construction project is evaluated. Particular attention is given to whether or not these methods of forecasting future values of cost indices significantly reduce the risk of financial loss due to cost escalation. Methods of applying the forecasted values of an appropriate cost index to obtain an estimate of the amount of escalation in a construction project are discussed in the next chapter.

3.2 Forecasting Methods

Empirical studies have shown that there is no single best forecasting method applicable to all situations (Goodrich 1989). To decide on which forecasting method is best for a given situation, it is necessary to critically examine the available data. This, and an understanding of the fundamentals of the various forecasting procedures are prerequisites for obtaining good forecasts.

Forecasting methods can be classified into three categories. The categories are: subjective methods, univariate methods and multivariate methods (Chatfield, 1975).

3.2.1 Subjective Methods

Subjective methods are based on human judgement of the various factors that may have an impact on the required forecast (Firth, 1977). These methods may range from intuitive and subjective decisions made by the decision makers (Nelson, 1973) to highly refined rating schemes that turn qualitative information into quantitative estimates.

Subjective forecasts are based on judgement, intuition, commercial knowledge and any other information the forecaster deems relevant. A wide range of factors may be taken into account depending on the knowledge and the experience of the forecaster. This makes subjective forecasts unique to the individual forecaster and therefore not reproducible.

Subjective methods and intuitive estimates are widely used in construction estimating and are most useful when there is insufficient historical data on the appropriate cost index. Mathematical methods cannot generally be used to make long range forecasts, that is, forecasts of duration over 2 years

(Firth, 1977). For such forecasts, subjective methods have to be used.

The forecasters intuition may often prove to be more reliable than any mathematical method (Chatfield, 1975). As such, subjective methods can be used as a basis of judging the accuracy of other methods by comparing the forecasts obtained using mathematical methods with the forecasters intuitive estimates. Since subjective forecasts are not reproducible they will not be analyzed and compared to other methods discussed herein.

3.2.2 Univariate methods

Univariate methods are based on fitting a model to the historical data of a given time series and extrapolating to obtain forecasts. There are many univariate methods available. These univariate methods include among others, extrapolation of trend curves, averaging, exponen smoothing, Box-Jenkins method, stepwise autoregression and adaptive filtering. Among these, the most popular are exponential smoothing and the Box-Jenkins method (Lye, 1990).

Exponential smoothing

The most commonly used exponential smoothing methods are the Holts-Winters family of models (Goodrich, 1989). These model time series using up to three components representing level, trend and seasonal influences. Recursive equations are used to obtain smoothed values for the model components. Each smoothed value of any model component is a weighted average of current and past data with the weights decreasing exponentially. Holts-Winters family of exponential smoothing models can be classified into three classes namely; simple exponential smoothing, Holt two-parameter smoothing and

Winters three-parameter smoothing (Goodrich and Stellwagen, 1987).

Simple exponential smoothing uses an equation to model the level of the series of the form:

$$L_t = \alpha Y_t + \alpha(1-\alpha)Y_{t-1} + \alpha(1-\alpha)^2 Y_{t-2} + \cdots \quad (3.1)$$

where:

α = the level smoothing parameter

Y_t = observed value of time series at time t

L_t = smoothed level at time t

This equation reduces to the recursive form:

$$L_t = \alpha Y_t + (1-\alpha)L_{t-1} \quad (3.2)$$

The forecasting equation is :

$$\hat{Y}_{t(m)} = L_t \quad (3.3)$$

where:

$\hat{Y}_{t(m)} =$ forecast for lead time m from time t

Holt two-parameter smoothing uses two equations to model level and trend. These are given in their recursive form by:

$$L_t = \alpha Y_t + (1-\alpha)(L_{t-1} + T_{t-1}) \quad (3.4)$$

$$T_t = \gamma(L_t - L_{t-1}) + (1-\gamma)T_{t-1} \quad (3.5)$$

where:

$T_t =$ the smoothed trend at time t

γ = trend smoothing parameter and other parameters are as previously defined.

The forecasting equation is :

$$\hat{Y}_{t(m)} = L_t + mT_t \tag{3.6}$$

Winters three-parameter smoothing involves three smoothing parameters for level, trend and seasonal effects. The smoothing equations are of the form:

$$L_t = \alpha\frac{Y_t}{S_{t-p}} + (1-\alpha)(L_{t-1} + T_{t-1}) \tag{3.7}$$

$$T_t = \gamma[L_t - L_{t-1} + (1-\gamma)T_{t-1}] \tag{3.8}$$

$$S_t = \delta\frac{Y_t}{L_t} + (1-\delta)S_{t-n} \tag{3.9}$$

where:

S_t = smoothed seasonal index at time t,

n = the number of periods in the seasonal cycle,

δ = seasonal index smoothing parameter and other parameters are as previously defined.

The forecasting equation is of the form:

$$\hat{Y}_{t(m)} = (L_t + mT_t)\hat{S}_{t(m)} \tag{3.10}$$

Simple exponential smoothing is appropriate for data which fluctuates around a constant or has a slowly changing level and is neither seasonal nor has any trend. Use of the Holts two-parameter model is appropriate for data which fluctuates about a level that changes with some nearly constant linear trend. Winters three-parameter model is used for data with trend and seasonal effects. The relevant exponential smoothing equations can be adjusted to represent data that has a damped exponential rather than linear trend (Goodrich, 1989).

All exponential smoothing equations give more weight to more recent values of data. The larger the values of the smoothing parameters the more emphasis on recent observations and less on the past. This is intuitively appealing for forecasting applications.

The smoothing parameters are normally obtained by either using iterative least squares or a grid search for the parameters that give the minimum squared error over the historical data. This calculation process requires a great number of computations which are normally incorporated into a computer program.

Exponential smoothing models are robust in that they are insensitive to changes in the data statistical structure (Goodrich, 1989). No assumptions about the statistical distribution of data are made in exponential smoothing and there is therefore no need to analyze diagnostic statistics given with most computer programs.

One of the main advantages of using exponential smoothing is that once the smoothing parameters have been estimated, only the previous forecast and the most recent observation have to be stored or are necessary to make a new forecast. This makes the calculation of a new forecast computationally very convenient.

Box-Jenkins Method

Box-Jenkins method (Box and Jenkins, 1976) models time series by making strong and explicit distributional assumptions about the underlying data generating process. The method uses a combination of autoregressive (AR), integration (I) and moving average (MA) operations in the general Autoregressive Integrated Moving Average (ARIMA) model to represent the correlational structure of a univariate time series.

An autoregressive operation of order p develops a forecast based on a linear weighted sum of previous data represented by:

$$\hat{Y}_t = \phi_1 + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{t-p} + e_t \tag{3.11}$$

where:

$\hat{Y}_t =$ forecasted value of series at time t,

$Y_{t-i} =$ observed value of time series at time $t - i$,

$\phi_i =$ weighting coefficient of the i^{th} previous period,

$e_t =$ error term at time t.

The coefficients are found by minimizing the sum of squared errors usually using a nonlinear regression routine.

A moving average operation of order q develops a forecast which is a function of the previous forecast errors using an equation of the form:

$$\hat{Y}_t = e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \cdots - \theta_q e_{t-q} \tag{3.12}$$

where:

$\theta_q =$ weighting coefficient for the q^{th} previous period.

The rest of the terms are as previously defined.

The autoregressive and moving average operations can only be applied to stationary time series. That is, they can only be applied to data which has a constant mean value with time. If a time series is non-stationary it has to be transformed to a stationary series by differencing before the AR and MA operations can be performed. Forecast values have to be transformed back to the original non-stationary state by the integration, (I), operation.

A three step procedure of identification, estimation and diagnostic checking was originally proposed by Box and Jenkins (Box and Jenkins, 1976) to select a model from the general class of ARIMA models. This iterative process is depicted in Figure 3.1. The identification process is deciding the best ARIMA(pdq) model to fit the data. This means identifying the degree of differencing d, the AR order p and the MA order q. The estimation process involves statistically estimating the model parameters. The diagnostic step involves examination of the residuals to ensure that the ARIMA modelling assumptions of independence, homoscedasticity, and normality of the residuals are not violated.

To use Box-Jenkins method, the data must have a strong correlational behaviour, and there should be sufficient data to permit reasonably accurate estimates of the parameters. It is suggested that there should be at least 50 observations for good estimates (Box-Jenkins, 1976).

The selected Box-Jenkins model which satisfies the diagnostic checks will generally fit the historical data well and the parameters estimated describe the data on which they are estimated. These parameters are estimates of unknown parameters. Therefore when the forecasts using the model are compared with future data not used in estimating the model parameters, the fit may not be as good (Abraham and Ledolter, 1983).

Other univariate methods

Other univariate methods include extrapolation of trend curves, averaging, stepwise autoregression and adaptive filtering. Extrapolation of trend is in-

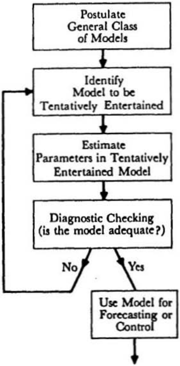


Figure 3.1: Stages in the iterative approach to model building (from Box and Jenkins, 1976).

herent in all the other univariate methods. Exponential smoothing encompasses averaging and is comparable to adaptive filtering (Claycombe and Sulivan, 1977). Stepwise autoregression can be regarded as some form of Box-Jenkins method (Granger and Newbold, 1977). For these reasons, an examination of the use of Box-Jenkins method and exponential smoothing to forecast construction cost indices should to reveal the benefits and limitations of using univariate methods to forecast construction cost escalation.

3.2.3 Multivariate Methods

Choice of type of multivariate method

Multivariate methods forecast a given time series taking into account observations of other variables. Generally, these models use equations developed by regression to represent the relationship between the dependent or endogenous variable and the exogenous or explanatory variables. Multivariate methods are either single equation models or simultaneous equation models.

In single equation models, the values of the explanatory variables determine the value of the dependent variable and the explanatory variables are not influenced by the values of the dependent variable. Simultaneous equation models take into account the simultaneous dependency between the dependent and explanatory variables.

The construction costs of any given single normal sized construction project seldom have any significant influence on the market forces which cause changes in cost. As such, single equation models are most applicable to construction. Therefore, in this treatise, only single equation models will be discussed.

Single equation models can be of either non-linear or linear specification.

A linear specification means that the dependent variable or some transformation of the dependent variable can be expressed as a linear function of the explanatory variable or some transformation of the explanatory variable. A model with a linear specification is the most appropriate to use with construction cost indices because construction cost components are generally additive.

The multivariate method most applicable to construction costs is therefore the single equation linear regression model. This regression model is of the form (Pindyck and Rubinfeld, 1976):

$$Y_{dt} = \beta_1 + \beta_2 X_{2t} + \beta_3 X_{3t} + \ldots + \beta_i X_{it} + e_t \tag{3.13}$$

where:

$Y_{dt} =$ the dependent variable at time t,

$\beta_i =$ coefficient of X_{it},

$X_{it} =$ the observed value of the i^{th} explanatory variable at time t,

$e_t =$ the error term at time t.

Requirements for use of regression models

The single equation linear regression model assumes that the residuals are normally distributed random variables with a mean of zero and a constant variance. It is also required that the explanatory variables are linearly related to the dependent variable (or can be transformed into some linear relation), and that explanatory variables are not collinear. In using regression models it is further assumed that the fitted regression model can be used beyond the range of the data at hand.

Building regression models requires theoretically plausible explanatory variables and sufficient historical data to estimate the model parameters. The models have to be tested through the examination of various statistical diagnostics to ensure that the assumptions on which the models are based hold.

Improvement to the linear regression model

The true relationship between the explanatory variables and the dependent variable is rarely known. Use is therefore made of empirical evidence to develop an approximate relationship. Thus, the explanatory variable may not sufficiently account for the variation in the dependent variable in which case use of dynamic regression may improve the model.

The term dynamic regression is adopted to represent multivariate models that combine the time series oriented dynamic features of autoregression and the effects of explanatory variables. In dynamic regression, the dynamic portion of the model, that is, the lagged dependent variables and the autoregressed (Cochrane-Orcutt) error terms, must be determined term by term by hypothesis testing. The specification of the explanatory variables must be such that all necessary explanatory variables are included. It should further be verified that all variables included in the model are statistically significant and that underlying assumptions are not violated.

Dynamic regression is generally used when the data available are long enough or stable enough to support a correlational model and the explanatory variables result in a definite increase in accuracy. The various measures of accuracy will be given in the examples that follow.

Attributes of regression models

Regression models have the advantage of being amenable to the investigation of various "what-if" scenarios. This is appealing because one can tell the influence of a change in an explanatory variable of interest, whether known, foreseen or probable.

One shortcoming of regression models is that if some crucial explanatory variable has not been varying in the past, it is not possible to include it in the model. Thus the effect of a change in such a variable cannot be assessed.

Problems are encountered in the use of regression models in cases where the value of the explanatory variables for use in obtaining forecasts are not known or require to be forecast. This will occur when there is no lag relationship between the explanatory and dependent variables or when the lag is insufficient.

3.3 Application of forecasting techniques

From the above discussion of the various forecasting methods, it would appear that considerable statistical expertise would be required to apply these methods. Fortunately, available computer software reduce the application process to the interpretation of the computer output and running various trials to obtain the best forecasting model. One such advanced statistical forecasting package is FORECAST PRO (BFS, 1988) developed by Business Forecast Systems which is used in the examples that follow.

The data used consist of 81 monthly values of the Prefabricated Wooden Building Industry Index (PWBII) published by Statistics Canada (1990) for the period January 1983 to September 1989. A listing of the data used is given in Appendix B. The first 72 observations are initially used for fitting the various models and the last 9 observations are used to compare the forecasts obtained using various methods. A plot of the data is shown in Figure 3.2. From a visual inspection, it can be seen that the series is non-stationary,

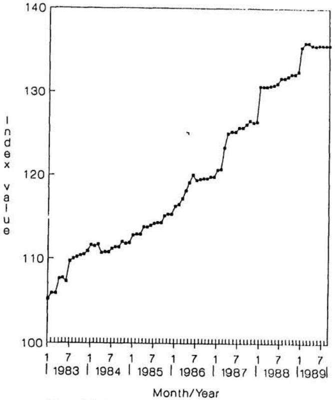


Figure 3.2: Plot of the Prefabricated Wooden Building Industry Index (PWBII)

has an upward trend and appears to be seasonal in the last half of the data. For such data, both Winters 3-parameter exponential smoothing and Box-Jenkins models are applicable. Dynamic regression can also be applied to obtain forecasts if suitable explanatory variables can be found. All these methods will be used and the best method will be chosen from the resulting forecasts. The use of analytical methods to forecast a construction cost index will thus be demonstrated by these examples.

3.3.1 Exponential Smoothing Modelling

Winters 3 parameter exponential smoothing model was fitted to the data using FORECAST PRO. The results are shown in Table 3.1. Since no

Table 3.1: Computer output for Exponential Smoothing model

Historical fit of exponential smoothing model	
Dependant variable:	PWBII
R-squared:	0.992
Adjusted R-squared:	0.992
Standard forecast error:	0.710986
F-statistic:	3020.771 (1.000)
Durbin-Watson:	1.784
Ljung-Box:	14.733 (0.744)
Standardized AIC:	0.725630
Standardized BIC:	0.760876
Three parameter Winters smoothing parameter values	
Level:	0.872749
Trend:	0.048131
Seasonal:	0.484918

statistical distribution assumptions have been made about the data, it is not necessary to closely scrutinize all the diagnostic statistics produced by the software package.

The smoothing parameter values are obtained by FORECAST PRO using an iterative search method to minimize the squared errors over the historical data. The computerized iterative search employs the simplex method of nonlinear optimization.

Examining the exponential smoothing parameters reveals that the seasonal parameter value is close to 0.5 indicating that the best forecast for the next seasons effect is half the last seasons effect and a weighted average of preceding seasonal effects. The small trend parameter value of 0.05 indicates that the smoothing model has a long memory of trend and distant trends have an effect on the forecasted trend component. The large value of the level parameter indicates that the model is highly adaptive to the last observed level of the series.

Figure 3.3 shows the plot of the fitted and forecasted values as compared to the actual figures. Though the model gives a visually good fit to the historical data, it does not forecast the turning point after the last fitted value. A one month lag between the fitted and actual values is apparent. This shows the strong influence of the previously observed level.

3.3.2 Box-Jenkins Modelling

Without software packages like FORECAST PRO, considerable skill and judgement is required to identify a suitable Box-Jenkins model to fit the data. The originally proposed method of identification through examination of autocorrelations and partial autocorrelations requires specialist knowledge (Firth, 1977). FORECAST PRO identifies an appropriate model automatically by minimizing the BIC statistic.

The AIC and BIC statistics, known as the Akaike Information Criterion and the Bayes Information Criterion respectively, evaluate how well a given model will perform relative to another. They do not have much statistical

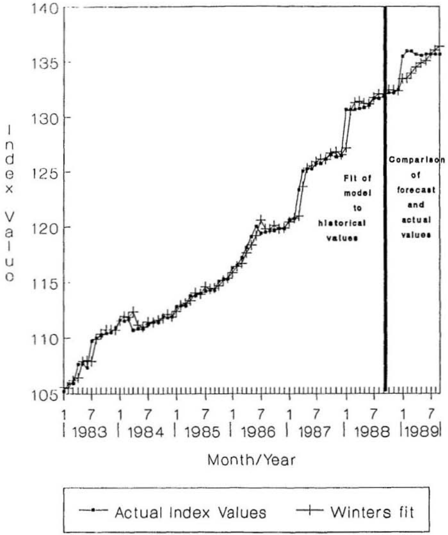


Figure 3.3: Forecast comparison: Winters 3 parameter exponetial smoothing

meaning by themselves. They reward goodness of fit to historical data and penalize model complexity. Based on empirical research, the model with the lowest AIC or BIC will generally be the most accurate (Goodrich and Stellwagen, 1977).

Use of these criteria in a computer package relieves the user from the lengthy identification, estimation and diagnostic steps in the Box-Jenkins methodology. The results of an application to the PWBII are shown in Table 3.2. Because of the strict distributional assumptions in the Box-Jenkins

Table 3.2: Computer output for Box-Jenkins model

Historical fit of Box-Jenkins model	
Dependant variable:	PWBII
R-squared:	0.991
Adjusted R-squared:	0.990
Standard forecast error:	0.763177
F-statistic:	7298.051 (1.000)
Durbin-Watson:	2.066
Ljung-Box:	11.454 (0.510)
Standardized AIC:	0.768608
Standardized BIC:	0.781052
Box-Jenkins model parameters	
B[1]:	0.956028
SIMPLE DIFF:	2

model, an examination of the diagnostic statistics is required.

The R-square statistic of 0.991 indicates that 99% of the variation of the index is explained by the model. This shows that the model fits the historical data very well. The F-statistic is highly significant (as indicated by the number 1.000 in brackets). This rejects the null hypothesis that the actual model parameters are 0.

The Durbin-Watson statistic and the Ljung-Box statistic test whether or not the residuals are correlated. Interpretation of the Durbin-Watson statistic requires reference to statistical tables. This statistic indicates the acceptance of the null hypothesis that there is no serial correlation in the first lag. A value close to 2 is desirable. The Ljung-Box statistic is not significant at both the 95% confidence level and the 99% confidence level. There is therefore no evidence of serial correlation in the first several lags of the residuals.

The autocorrelations of the residuals were examined using FORECAST PRO and were found to exhibit no systematic pattern. They were also small in magnitude being less than 2 times the standard error.

Comparison of the AIC and BIC for the Box–Jenkins and exponential smoothing model indicate that on the basis of these criteria the exponential smoothing model is probably more accurate. However, this is not conclusive because the most important criterion in forecasting is how good the forecasted values fit the actual values and not the goodness of fit to historical data.

Figure 3.4 shows the plot of the actual, fitted and forecast values. The model gives a visually good fit to the historical data but does not forecast the turning point in the data right after the last fitted value.

3.3.3 Dynamic Regression Modelling

Dynamic regression requires additional variables which are correlational significant and theoretically plausible to explain the dependent variable. In this example, various indices published in Statistics Canada Catalogue 62–

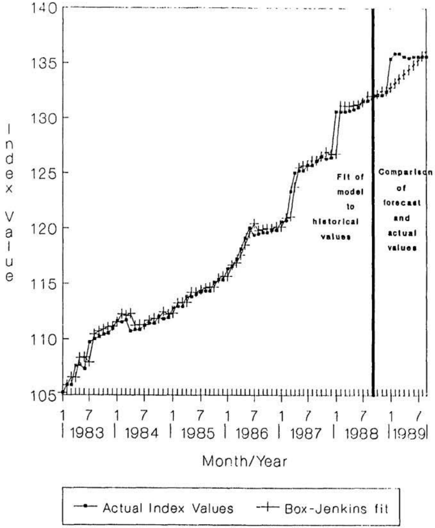


Figure 3.4: Forecast comparison: Box-Jenkins

007 (Statistics Canada, 1990) were used as possible explanatory variables to forecast the PWBII. These include the Union Wage Rate Index (UWRI), the Construction Building Materials Price Index (CBMPI), the Commercial Bank Lending Rate index (CBLR), the Sawmill and Planing Mill Products Index (S&PMPI) and the Architectural Materials Index (AMI). A listing of the values of these indices from January 1983 to September 1989 is given in Appendix B. These variables were plotted and their plots compared with the PWBII. The plot of the values of these indices with time is given in Appendix B. Possible lag relationships and possible transforms were sought through a visual inspection of the plots.

Table 3.3 shows the results of the initial trial. The value of the R-square statistic is quite high (97%). This is probably due to trying to develop a model using a large number of explanatory variables. Each additional explanatory variable can only increase the R-square value yet may not improve the models forecasting accuracy.

The Durbin-Watson and the Ljung-Box statistics indicate problems of serial correlation. This means the model has to be adjusted because the assumptions on which it is based do not hold.

The coefficients of four of the explanatory variables are not significant at the 95% confidence level implying that these variables should either be omitted, transformed or lagged. Some of these explanatory variables may appear not to be statistically significant because of multicollinearity. FORECAST PRO, however, does not provide tests for multicollinearity.

Various trials using lagged dependent and transformed explanatory variables were performed until a near optimum regression model was obtained as one possible solution. There are a number of available selection strate-

Table 3.3: Computer output for Dynamic Regression model: initial trial.

Historical fit of dynamic regression model	
Dependant variable:	PWBII
R-squared:	0.965
Adjusted R-squared:	0.962
Standard forecast error:	1.564319
F-statistic:	303.379 (1.000)
Durbin-Watson:	0.557
Ljung-Box:	120.896 (1.000)
Standardized AIC:	1.627879
Standardized BIC:	1.789863

Variable	Coefficient	Standard error	T-stat	Prob
UWRI	0.361754	0.073729	4.907	1.000
CBMPI	0.351710	0.137117	2.565	0.990
CBLR	0.064706	0.044185	1.464	0.857
S&PMPI	0.000548	0.039341	0.014	0.011
AMI	0.120562	0.129265	0.933	0.649
Constant	7.109199	5.230716	1.359	0.826

gies that can be used to empirically construct the required regression model. For this example, the backward elimination procedure, whereby the selection process started with the largest possible model, was used. Other selection strategies include forward selection and stepwise regression (Abraham and Ledolter, 1983). The choice of the search strategy to use depends on the forecaster's individual preference since all methods produce a regression model with the necessary statistical attributes. The result of the backward elimination selection strategy is given in Table 3.4. The explanatory variables found

Table 3.4: Computer output for Dynamic Regression model: final trial.

Historical fit of dynamic regression model				
Dependant variable:		PWBII		
R-squared:		0.992		
Adjusted R-squared:		0.992		
Standard forecast error:		0.658523		
F-statistic:		2456.983 (1.000)		
Durbin-Watson:		2.032		
Ljung-Box:		14.390 (0.724)		
Standardized AIC:		0.674757		
Standardized BIC:		0.711028		
Variable	Coefficient	Standard error	T-stat	Prob
UWRI[-5]	0.082996	0.033897	2.448	0.986
AMI[-12]	0.111773	0.031417	3.558	1.000
PWBII[-1]	0.797042	0.059730	13.344	1.000

to give the statistically satisfactory model shown in Table 3.4 are:

UWRI[-5] = the UWRI lagged 5 months,

AMI[-12] = the AMI lagged 12 months,

PWBII[-1] = the dependent variable lagged 1 month.

This model implies that the value of the PWBII at any given time can be forecast using values of the AMI twelve months before, the UWRI five months before and the PWBII one month before.

The signs of the coefficients of the explanatory variables are all positive. This agrees with *a priori* expectations that the PWBII will increase with increases in the UWRI and the AMI. In this model there is no problem of serial correlation as evidenced by the Durbin-Watson and the Ljung-Box statistics. All independent variables are significant at the 95% confidence level. This model explains 99% of the variation in the PWBII as indicated by the R-square statistics and therefore fits the historical data well. Figure 3.5 shows the plot of the fitted and forecast values as compared to the actual values. The regression model appears to attempt to account for the turning point in the data after the last fitted value.

This example demonstrates some of the problems of using regression models. Though, from theoretical considerations, interest rates affect construction costs, the CBLR was not found statistically significant enough to be used in the model to forecast or explain the variation in the PWBII. Thus factors which are known to affect construction costs may not be found useful in forecasting by regression models even when data on the variation of these factors exist. Another problem is that though a lag between the AMI and the PWBII would be expected on theoretical grounds, the 12 month lag found statistically significant would seem too long and is therefore suspect. To reject this lag as spurious, it would be necessary to obtain detailed information on the formulation of both the AMI and the PWBII. Formulation of indices is discussed in Chapter 6.

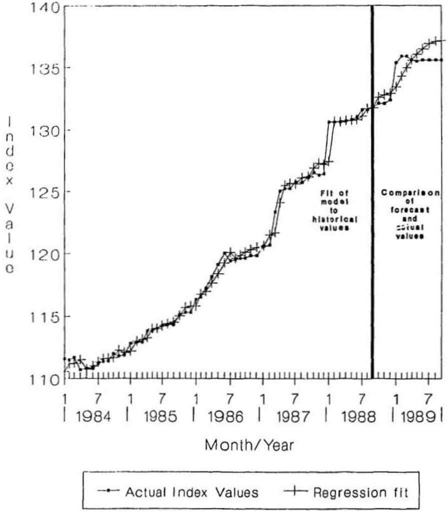


Figure 3.5: Forecast comparison: Dynamic Regression

3.4 Choice of Forecasting Model

In order to decide which of the three fitted models would be best to use for forecasting the PWBII, the following criteria are used:

1. The accuracy of the forecasts and not the historical fit to the data will be considered.
2. A more complex model will only be recommended if it undoubtedly improves the forecasting accuracy.

Various methods of measuring forecast accuracy exist. Mahmoud (1984) surveys the following: the mean square error, the mean percentage error, the mean absolute percentage error, Theil's U-statistic, the root mean square error, the mean error, the mean absolute deviation, turning points, and hits and misses.

In forecasting construction cost escalation, it is most convenient to use a measure of accuracy consistent with the normal measure of accuracy used in construction cost estimation. The measure of accuracy used in construction cost estimation is normally the percentage error of the estimate. Of particular interest to the cost estimator would also be the turning points in the time series where the rate of cost escalation changes. As such, to measure the accuracy of forecasts, the mean absolute percentage error (M.A.P.E.) and the precision with which a method forecasts turning points is examined.

In terms of complexity, exponential smoothing is the simplest method to apply. The other methods should therefore be tested to examine whether they are undoubtedly more accurate and forecast the turning points much better than exponential smoothing.

To guard against spurious accuracy, three forecasting scenarios were used. These scenarios were obtained by fitting the different models to the data and forecasting 9 months ahead but using three different last fitted values. The three forecasting scenarios are forecasting nine months ahead beginning with: January 1989, July 1988, and October 1988. The various forecasts are given in Table 3.5, 3.6 and 3.7. These tables show that Winters three-parameter

Table 3.5: Mean absolute percentage error of various forecast models and scenarios.

Nine month forecast beginning with January 1989

Period	Actual PWBII value	Expo-nential forecast	Abso-lute error	Box-Jenkins forecast	Abso-lute error	Regre-ssion forecast	Abso-lute error
1-1989	135.4	133.40	2.00	132.81	2.59	133.46	1.94
2-1989	135.9	133.43	2.47	133.23	2.67	134.30	1.60
3-1989	135.9	133.90	2.00	133.64	2.26	134.97	0.94
4-1989	135.6	134.48	1.12	134.05	1.55	135.58	0.02
5-1989	135.5	134.81	0.69	134.47	1.03	136.06	0.56
6-1989	135.6	135.04	0.56	134.88	0.72	136.48	0.88
7-1989	135.6	135.67	0.07	135.30	0.30	136.92	1.32
8-1989	135.6	136.01	0.41	135.71	0.11	137.07	1.47
9-1989	135.6	136.36	0.76	136.12	0.52	137.17	1.57
	M.A.P.E.		0.83		0.96		0.84

exponential smoothing yields superior forecasts in two of the three forecasting scenarios and that regression modelling gives a superior forecast in the other.

Exponential smoothing is the simplest of the three types of forecasting models. From the evidence in Tables 3.5, 3.6 and 3.7 none of the more complex models give undoubtedly better forecasts of the PWBII than the

Table 3.6: Mean absolute percentage error of various forecast models and scenarios (continued).

Nine month forecast beginning with July 1988

Period	Actual PWBII value	Expo-nential forecast	Abso-lute error	Box-Jenkins forecast	Abso-lute error	Regre-ssion forecast	Abso-lute error
7-1988	131.6	131.66	0.06	131.47	0.13	131.07	0.53
8-1988	131.6	132.07	0.47	131.94	0.34	131.28	0.32
9-1988	131.8	132.46	0.66	132.41	0.61	131.50	0.30
10-1988	132.1	133.04	0.94	132.88	0.78	132.44	0.34
11-1988	132.4	133.34	1.24	133.35	1.25	133.13	1.03
12-1988	135.4	133.58	1.18	133.82	1.42	133.83	1.43
1-1989	135.4	134.58	0.82	134.30	1.10	134.68	0.72
2-1989	135.9	134.70	1.20	134.77	1.13	135.33	0.57
3-1989	135.9	135.21	0.69	135.24	0.66	135.81	0.09
	M.A.P.E.		0.61		0.62		0.44

Table 3.7: Mean absolute percentage error of various forecast models and scenarios (continued).

Nine month forecast beginning with October 1988

Period	Actual PWBII value	Expo-nential forecast	Abso-lute error	Box-Jenkins forecast	Abso-lute error	Regre-ssion forecast	Abso-lute error
10-1988	132.1	132.38	0.28	132.25	0.15	132.68	0.58
11-1988	132.1	132.66	0.56	132.69	0.59	133.32	1.22
12-1988	132.4	132.88	0.48	133.14	0.74	133.98	1.58
1-1989	135.4	133.84	1.56	133.58	1.82	134.81	0.59
2-1989	135.9	133.94	1.96	134.03	1.87	135.44	0.46
3-1989	135.9	134.42	1.48	134.47	1.43	135.92	0.02
4-1989	135.6	135.00	0.60	134.92	0.68	136.38	0.78
5-1989	135.5	135.35	0.15	135.36	0.14	136.73	1.23
6-1989	135.6	135.62	0.02	135.81	0.21	137.05	1.45
	M.A.P.E.		0.59		0.63		0.65

Winters three-parameter model. Based on the previously stipulated criteria, exponential smoothing would be the best method to use in these circumstances to forecast the PWBII.

It should be noted that due to the specification of the regression model, forecasts of the PWBII can only be made five months ahead without having to first obtain forecasts of the UWRI. In obtaining the nine month forecasts given in Tables 3.5, 3.6 and 3.7, actual values for the UWRI were used up to four months ahead. This gave the regression forecast for the last four months of the nine month forecast period unrealistic accuracy. Nonetheless, the regression forecasts were less accurate than those from exponential smoothing in two of the three scenarios. It is therefore not necessary to investigate the accuracy of the regression model when four month forecasts instead of actual values of the UWRI are used.

Nevertheless, the regression model could still be useful in some circumstances, such as in the case when the forecaster knew of on-going labour union negotiations which were likely to increase the UWRI by some estimated amount. The regression model could be used to forecast the effect of this increase on the PWBII. This illustrates one of the benefits of developing a regression model.

3.5 Impact of forecasting techniques on the treatment of escalation

With the availability of user friendly forecasting software, many complex statistical forecasting techniques can now be used to forecast the required construction cost escalation rate. This can be done provided the practitioner can interpret the results produced by these software. The foregoing discussion and examples give the underlying theory and demonstrate the application. limitations and benefits of using available forecasting techniques.

The analytical forecasting techniques discussed herein are only valid for short term forecasting. This is because these techniques are based on empirical relationships derived from past data. There is no rational basis for assuming that there will be no change in the empirical relationships so derived in other than the near future. In the literature reviewed, no analytical forecasting technique has been found capable of forecasting cost escalation for a construction project lasting two years or more.

Being able to give quantitative forecasts of escalation does not eliminate the risk caused by cost escalation. This is so because none of the available techniques can forecast escalation caused by unpredictable occurrences which include major events like the outbreak of war and government action. The analytical methods available are only useful in forecasting for short construction projects in stable conditions. Construction cost escalation, with or without the use of these forecasting methods, still remains a risk to be borne by either the contractor, the owner, or both depending on the terms of the construction contract.

Chapter 4

APPLICATION OF FORECASTED ESCALATION RATE

4.1 Introduction

To obtain an estimate of the amount of escalation for a construction project, the forecasted escalation rate has to be applied to the expenditure cash flow. The appropriate escalation rate is the percentage increase for a given period of the forecasted values of an appropriate cost index. Methods of forecasting values of the cost index are described in the preceding chapter. This chapter will discuss methods of applying the forecasted values of an appropriate cost index to the expenditure cash flow and methods of estimating the expenditure cash flow.

4.2 General computation procedure

In order to compute the amount of escalation for a given construction project the following data is required:

1. The future values of an appropriate cost index.
2. The expenditure cash flow of the project.

This data is used to compute the amount of escalation in the manner shown in Table 4.1 and discussed below.

Table 4.1 illustrates how the amount of escalation is calculated given the unescalated expenditure within each time interval and appropriate cost index values. Table 4.1 depicts computations for a three year project whose unescalated cost is 40.3 million dollars. The escalation factors and the unescalated cash flow figures displayed in Table 4.1 are adapted from Stukhart (1982). Construction of the project shown in Table 4.1 is planned to begin three months from the date of estimating. The total project escalation cost, E_T, is calculated from:

$$E_T = \sum_{all\ i} E_i \tag{4.1}$$

where E_i is the escalation cost in time interval i. E_i is obtained from:

$$E_i = P_i(F_i - 1) \tag{4.2}$$

where P_i is the unescalated expenditure cash flow in time interval i and F_i is the escalation factor for time interval i. F_i is given by:

$$F_i = \frac{I_i}{I_0} \tag{4.3}$$

where I_i is the cost index at time interval i and I_0 is the cost index at the time of estimating (or at the time of tender).

The various required cost index values can be forecast by methods discussed in Chapter 3. The unescalated expenditure cash flow for the whole project is required in order to obtain the various values of P_i.

It would be ideal if the actual unescalated expenditure cash flow were known with certainty. Unfortunately, the only time the expenditure cash flow is known with certainty is at the end of a project. As a result, the required cash flow has to be estimated or forecast.

Table 4.1: Computation of escalation amount from estimated monthly expenditure and forecasted cost index values

Number of months from date of estimate i	Unescalated cash flow for 3 month interval P_i	Escalation factor F_i	Escalation cost in 3 month interval E_i
3	0	1.0085	0
6	600,000	1.0252	15,120
9	1,050,000	1.0432	45,360
12	2,900,000	1.0610	176,900
15	3,000,000	1.0791	237,300
18	3,600,000	1.0975	351,000
21	5,100,000	1.1162	592,620
24	6,200,000	1.1353	838,860
27	6,800,000	1.1546	1,051,280
30	6,100,000	1.1743	1,963,230
33	2,500,000	1.1944	486,000
36	1,600,000	1.2147	343,520
39	850,000	1.2354	200,090

Total project escalation cost, E_T = \$ 5,401,280

There are two methods that can be used to estimate or forecast cash flow projections of expenditure versus time namely:

1. Based on a planned progress schedule.
2. Based on cost flow models.

4.3 Cash flow projections from a planned progress schedule

Cash flow projections from a planned progress schedule are obtained by first calculating the work quantities within every time interval in accordance with the planned progress schedule. These quantities are then multiplied with their respective unit costs to obtain the expenditure within each time interval. The forecasted escalation rate is then applied to the expected expenditure within a each time interval using the general computation procedure discussed in the preceding section, Section 4.2.

The planned progress schedule can be produced manually or with the use of computer scheduling packages.

4.3.1 Use of computer scheduling packages

Network based computer packages can be used to generate cumulative cost flow projections for a construction project. There are a variety of software packages for use in construction scheduling and estimating available on the market. Examples of such packages are Microsoft Project (MC, 1985), Primavera Project Planner (PS, 1986), Timeline (BSC, 1986) and Precision Estimating Plus (TSC, 1987). These computer packages generally use the Critical Path Method (CPM) in project network analysis (Peurifoy and Ledbetter, 1985). This method involves the identification of specific activities, their duration and their interrelationships.

Network based computer packages typically give cost envelopes defined by the cumulative cost flow profiles for early and late start costs as depicted in Figure 4.1 (Suhanic, 1986). The early start cost profile is the project's cumulative cost flow profile when all activities are started and completed at the earliest time each activity could be executed within the project's technological and physical constraints without delaying completion of the project. Similarly, the late start cost profile relates to all activities being started and completed at the latest time possible.

The early and late start expenditure profiles demarcate the limits within which the projects actual expenditure profile is expected to be if work is executed in accordance to a planned progress schedule. The estimator has to select a single cost flow profile within these limits to use in computing the estimated escalation costs for the project.

The author recommends use of a curve which is the average of the early and late start profiles if the estimator has no *a priori* expectations of the project following either the early start or the late start profiles. This is because the average curve takes into account all activities not starting at the earliest start dates due to unexpected delays and changing priorities during project execution. The average curve also takes into account the project, on average under normal circumstances, maintaining progress well above the late start curve. The main difficulty experienced in using the average curve is that most scheduling packages do not produce the average curve automatically and thus the estimator may have to plot or compute its coordinates manually.

Since no probabilities associated with the early and late start profiles are

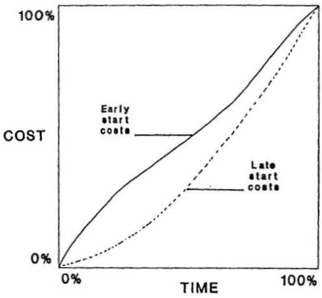


Figure 4.1: Form of computer generated cost envelope (Suhanic, 1986)

given, the estimator may have no rational basis for selecting either cost flow profile. The generation of two curves is thus useless for escalation estimation purposes unless the estimator has reason to believe that the project will follow either the early start or the late start profiles.

The difficulty in assigning probabilities to possible project and activity durations and the difficulty in selecting a single most probable cost flow profile can be overcome by the application of the Programme Evaluation and Review Technique (PERT).

4.3.2 Use of the Programme Evaluation and Review Technique (PERT)

Unlike the use of CPM, use of PERT is probabilistic in that it takes into account the possibility of activities being completed within a range of possible duration times. Use of CPM, on the other hand, is deterministic in that it requires identification of specific duration times for every activity. PERT therefore deals with the difficulty of planning projects for which durations of specific activities cannot be reliably estimated. This is useful in construction cost estimating because of the considerable amount of subjective evaluation that is often used in determining activity durations.

Both CPM and PERT assume that specific activities and their precedence relationships can be clearly defined for a particular project. The PERT system, however, recognizes that specific activity durations are in essence means of a distribution. By applying probability theory to the distribution and expressing the computed values in standard form, the probability that a particular project or activity will be completed before or after a specified time can be ascertained.

In the use of PERT it is necessary to invoke the Central Limit Theorem which may be stated as follows (Harris, 1978):

> If independent probability distributions are summed, the mean of the sum is the sum of the individual means, the variance of the sum is the sum of the individual variances, and the distribution of the sum tends to the shape of the normal curve regardless of the shape of the individual distributions.

To utilize the Central Limit Theorem and to effectively apply PERT to a project network, it is necessary that any path to be considered in the network must contain a sufficient number of activities. The minimum required number of activities range from four to ten. Experts have divided opinion on what the exact minimum number of activities should be (Harris, 1978).

In invoking the Central Limit Theorem, the following assumptions are made about the various activities in the projects network:

1. The duration of all activities are randomly distributed with a variety of duration distributions. The exact form of the various duration distributions need not be specified.
2. For each activity, it is possible to specify the most likely duration m, the optimistic duration a, and the pessimistic duration b.
3. All varieties of duration distributions can be converted to a common distribution.

Whenever these assumptions are valid, the Central Limit Theorem applies and the project duration can be assumed to be normally distributed.

Any normal distribution is completely defined by its mean and standard deviation. The mean of the project duration is the overall expected project duration, T_e. It is necessary to compute the overall expected project duration T_e, and its standard deviation, S_T, in order to completely define the distribution of the projects duration.

The overall project duration, T_r, is obtained by calculating the following along the critical path:

$$T_r = \sum t_e \tag{4.4}$$

where t_e is the expected activity duration. The expected activity duration, t_e, is obtained from:

$$t_e = \frac{a + 4m + b}{6} \tag{4.5}$$

where a,m, and b are as previously defined.

The overall project standard deviation, S_T, is obtained by calculating the following along the critical path:

$$S_T^2 = \sum S^2 \tag{4.6}$$

where S is the activity standard deviation. Equation 4.6 can only be used without violating underlying statistical assumptions if the activities along the critical path are statistically independent. Each activity's standard deviation, S, is obtained from:

$$S = \frac{b - a}{6} \tag{4.7}$$

where a and b are as previously defined.

With the mean and standard deviation of the projects duration obtained, the probabilities associated with various completion times can be calculated using the theory of the normal distribution. The theory of the normal distribution is well described in many statistics and probability textbooks. The estimator can thus use PERT to compute the probabilities of various completion time scenarios and the use of PERT will generate one single cost flow profile associated with the expected project duration.

4.3.3 Shortcomings in the use of schedules

The main shortcomings of obtaining cash flow projections from a planned progress schedule regardless of whether the schedule is obtained either manually, using computer scheduling packages, or using PERT are:

1. The procedure requires a detailed estimate with detailed information such as required crews and work item costs. As such, it cannot be applied when producing unit price, elemental or preliminary estimates where such detailed information is normally not available .
2. This procedure cannot be used by the owner or consultant of a construction project even when in possession of a detailed cost estimate submitted by a contractor. This is because even with a detailed cost estimate submitted by a contractor, the owner or consultant will not have the required detailed breakdown of labour, equipment, material and other costs for each interval period as required to obtain cash flow projections from a planned progress schedule.
3. The resulting cash flow forecast from the use of a detailed schedule is not necessarily more accurate than that obtained using cost flow models. This is so because cost flow control during construction is a dynamic process which, coupled with the large number of interlinked work items and the stochastic nature of the scheduling process, implies deviations between the planned and actual cash flows are expected to occur. Drake (1978) reports that based on his experience, the use of cost flow models to produce forecasts often proved more accurate than forecasted cash flows based on detailed data. Mahler and Mazina (1982) reiterate: "Often ...historical; models more closely represent the actual field construction sequences than do formal schedules."

4.4 Cash flow projections from cost flow models

4.4.1 Basis of cost flow models

Historical records of completed construction project costs can be used to obtain cost flow projections for similar construction projects using cost flow models. Past cost information of completed projects is widely used in estimating and has been shown to be of immense value at various estimating stages. The usefulness of this information in all types of estimates whether preliminary, elemental analysis, unit price or detailed has been well documented by Ahuja and Campbell (1988).

A number of published results indicate that expenditure versus time characteristics for a given type of construction have a consistent pattern. These include, among others, publications by Patten (1987), Peer (1982), Carr et al (1974), Drake (1978), Mahler and Mazina (1982), Singh and Woon (1984), Brink and Dijik (1984) and Christian and Kallouris (1990). To illustrate this phenomenon, the cumulative percentage value of work executed versus percentage of time for two hospitals built within the last ten years in Newfoundland are depicted in Figure 4.2. In Figure 4.2, the percent complete on the ordinate represents the percentage of hospital costs at any point to total hospital project costs and percent time represents the percentage of construction time at any point to total hospital construction time.

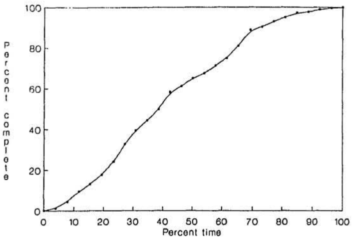
As shown in Figure 4.2, these two hospitals give similar patterns of expenditure versus time. Cost flow models are based on this phenomenal similarity of cost flow profiles of similar projects executed under similar conditions.

4.4.2 Characteristic shapes of cost flow profiles

Various cost flow models for forecasting the cumulative cost flow of construction projects have been proposed. These models can be used to calculate cumulative construction costs which typically form an S shaped curve when plotted against time. This shape comes about because construction work, due to physical constraints, has to follow some technological sequence and costs are incurred on a continuous basis as work progresses.

Three S-curves typify the wide range of shapes that may be formed by

Burin Penisula District Hospital



Clarenville District Hospital

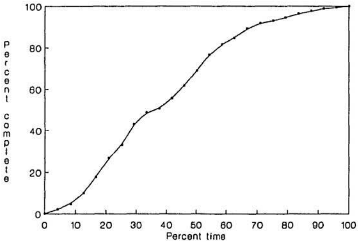


Figure 4.2: Cost flow profiles for two hospital projects (DPWT, 1990)

various project's cumulative cost flow. These are the model S-curve, the back loaded S-curve and the front loaded S-curve as shown in Figure 4.3.

The model S-curve is typically formed by normal building construction or a green field project. It shows work slowly accelerating at the beginning with a steady but faster rate of work during the middle period and gradually tailing off towards the end. The front loaded S-curve represents a project in which there is a heavy outlay of resources at the beginning. It would typically be formed by heavy civil construction or in cases where crashing a project from day one is necessary as in the repair of disaster damage. The back loaded S-curve represents a project where heavy expenditure comes at the end such as in plant construction where equipment is installed near the end of the project or in hydro-electric projects.

From the characteristics of a given project one can decide which shape of S-curve is appropriate. Similar projects have similar S-curves, thus the exact form of the S-curve to use in estimating escalation costs of the project at hand can be obtained from the analysis of historical costs of completed similar projects.

4.4.3 Historical cost analysis

Since the selected S-shaped curve formed by the historical costs of completed similar projects will normally represent a different time and cost base, it is necessary to manipulate it to suit the project at hand. The first step is to convert the historical cost flow for the selected completed project into comparable costs. This process can be referred to as normalizing the costs to a comparable basis (Rapier, 1990). Normalizing is done to remove any changes, that may have occurred during the execution of the selected com-

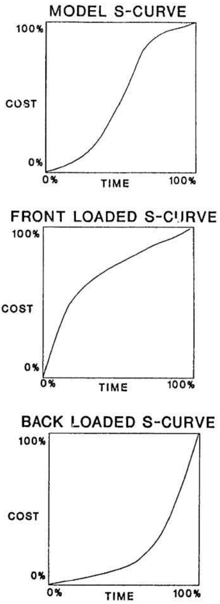


Figure 4.3: Various forms of S-curves (Campbell, 1990)

pleted project, which are not necessary for modelling the cost flow of the project at hand.

Figure 4.4 gives an example of normalizing the historical costs of a completed project to obtain the required S-curve. In this case, the normalizing is done to obviate the effects of a labour strike which lasted five months. During the strike, construction work came to a complete halt and cumulative costs did not increase with time during the strike period. Normalizing is achieved in this example by removing the horizontal segment of the curve formed by the projects costs before normalizing and reducing the total project time by five months yet keeping total project costs the same.

Normalizing entails doing the following (Hanna, 1990):

1. Removing any change order costs, costs of variation works or costs due to changes in scope that occurred during the execution of the completed project from the completed projects cumulative costs.
2. Adjusting the selected completed project's cost flow profile to obviate the effects of any abnormal events that occurred during the execution of the completed project, for example, abnormally severe weather conditions or labour strikes. This adjustment is done in the manner previously discussed in relation to Figure 4.4.

After normalizing the historical costs, the next step is to express the costs and time of the normalized project's cost flow profile as a percentage of total project costs and total project time. The resultant S-curve will have the costs and times expressed as a percentage and can be directly applied to a similar project with a different estimated total cost and a different estimated total construction time. There are then basically two methods of using the resultant S-curve to compute escalation costs. These are by interpolation and by the use of a mathematical equation.

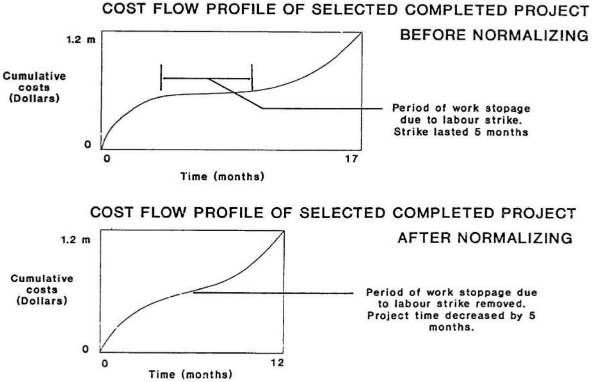


Figure 4.4: Example of normalizing historical costs of selected completed project (Hanna, 1990)

4.4.4 Interpolation

In this method, the estimator divides the time axis which is the abscissa of the S-curve into the number of payment periods and reads on the ordinate the corresponding percentage complete. The difference in the value of the cumulative percentage complete between two time periods gives the percentage of the contract sum that is to be executed within that period. This percentage can be multiplied by total project costs to obtain the amount of expenditure in the given time period. The general computation procedure previously discussed in Section 4.2 can then be used to obtain the total project escalation costs.

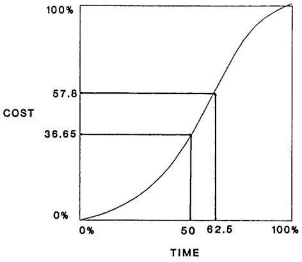
Figure 4.5 illustrates the steps involved in the application of this method to obtain the expenditure in a given period for a hypothetical project. P is the unescalated amount to be spent in June 1990. The hypothetical total unescalated contract cost is \$ 107,500.

The disadvantage of this method is that errors may occur due to inaccuracies in reading of the coordinates of the curve. Furthermore, the selected cumulative cost flow for a completed project may have a number of erratic deviations or discontinuities which have to be smoothed out. Smoothing is not done automatically when interpolating manually. Manual smoothing prior to interpolation introduces personal or human errors. Use of an equation, on the other hand, automatically smooths any erratic deviations and reduces personal and human errors.

4.4.5 Use of an equation

The other way of obtaining the required expenditure per period is by the use of a mathematical equation to represent the S-curve. This equation can be

SELECTED S-CURVE



STEPS IN FINDING P FOR JUNE 1990

1. 1/7/1990 IS AT 62.5% TIME
2. 1/6/1990 IS AT 50 % TIME
3. 62.5% TIME CORREPONDS TO 57.8% COST
4. 50% TIME CORRESPONDS TO 36.65% COST
5. % COST FOR JUNE 1990 = (57.8 - 36.65) = 21.15
6. P FOR JUNE 1990 = 21.15% X 107,500 = 22,740

Figure 4.5: Example of estimating monthly expenditure by interpolation from selected S-curve

incorporated into a spreadsheet generated by computer software packages like Lotus 123 or Quattro to obtain the values of the required cash flow. There are a number of equations that have been proposed to represent S-curves.

Various suggested equations

Harris (1978) discusses an equation in which the curve is divided into three portions by two control points. The points are one located at one third of the time and one quarter of the cost and the other located at two thirds of the time and three quarters of the cost. Linear variation was assumed for the middle part of the curve and parabolic variation at the ends. He thus described the curve with the following three typical equations:

$$\begin{array}{ll} First\ part: & y = 0.0225x^2 \\ Middle\ part: & y = 1.5x - 25 \\ Last\ part: & y = -122 + 4.5x - 0.0225x^2 \end{array} \qquad (4.8)$$

Where y is the percentage of total cost and x is the percentage of total time. The main shortcoming of this form of representation is that it will not apply to many projects, for instance those with front loaded or back loaded distributions which do not possess the linear portion.

Carr et al (1974) discusses the use of the sine square curve of the form:

$$y = sin^2(90x) \qquad (4.9)$$

where y and x are as previously defined, and Peer (1982) investigates the mathematical representation of S-curves with the aid of *tanh* and *error* functions. Both authors conclude that the use of polynomial regression gives a better fit and is a better way to mathematically represent S-curves.

Drake (1978) from a statistical study of a large number of schedules proposes that S-curves can be represented by equations of the form:

$$Y = S[X + CX^2 - CX - \frac{1}{K(6X^3 - 9X^2 + 3X)}] \qquad (4.10)$$

Where:

$Y =$ cumulative monthly value of work executed.

$X =$ ratio of month n in which expenditure Y occurred to total contract period in months.

$S =$ Contract sum.

C and K = parameters.

This representation has the disadvantage that its functional form does not render it easily adaptable for routine estimation procedures. Furthermore, this representation was developed for hospital schemes and as such may need modification before application to other types of projects with different basic S-curve shapes.

Carr et al (1974) and Peer (1982) use third order solutions of polynomial regression to obtain curves of the form:

$$y = a + bx + cx^2 + dx^3 \qquad (4.11)$$

Where y and x are as previously described and a,b,c and d are constants.

Polynomial regression is flexible in that it can be applied to various shapes of curves to obtain characteristic equations. There are a number of computer software packages available that can perform the required regression analysis (Myers, 1986), and therefore, for any selected curve one can quickly obtain the mathematical equation using polynomial regression.

Use of the beta distribution

The litrature reviewed makes no mention of the use of probability density functions to represent S-curves. Beta distributions, which are probability density functions, are rich enough to provide models for most random variables having a restricted range of possible values, for example, random variables restricted to range from zero to one or from zero to one hundred (Olkin et al., 1980). Since percentage of total vost and time range between zero and one hundred, beta distribution can in theory be used to represent the S-curves formed by a projects cumulative cost flow profile.

If a variable Y has a beta distribution then the probability density function $f_Y(y)$ of Y has the form:

$$f_Y(y) = \begin{cases} \frac{y^{r-1}(1-y)^{s-1}}{B(r,s)}, & if \ \ 0 \le y \le 1 \\ 0\,, & if \ \ y < 0 \ \ or \ \ y > 1. \end{cases} \tag{4.12}$$

where r and s are positive numbers and are parameters of the beta distribution. The constant $B(r, s)$ is called the beta function defined by:

$$B(r,s) = \frac{\Gamma(r)\Gamma(s)}{\Gamma(r+s)} \tag{4.13}$$

where $\Gamma(r)$ and $\Gamma(s)$ are gamma functions of r and s respectively.

To fit the beta distribution to a projects cost data, it is nessesary to estimate the numbers r and s from the costs of similar completed projects using the equations:

$$r = \hat{\mu}_Y[\frac{\hat{\mu}_Y(1-\hat{\mu}_Y)}{\hat{\sigma}_Y^2} - 1] \tag{4.14}$$

$$s = (1-\hat{\mu}_Y)[\frac{\hat{\mu}_Y(1-\hat{\mu}_Y)}{\hat{\sigma}_Y^2} - 1] \tag{4.15}$$

where $\hat{\mu}_Y$ is the average and $\hat{\sigma}_Y^2$ is the variance of the completed projects cost.

While the theoretical aspects of the beta distribution cover all types of shapes it is not practical for immediate adoption and routine use in the construction industry because of the complexity of Equation 4.13 which cannot be inserected in the widely used speadsheet programs.

The above is by no means an exhaustive review of available possible cost flow models. There are various other cost flow models which have been suggested in the literature reviewed. For example, Bashambu (1980) discusses the use of the following equation to model the cost flow for construction of nuclear power plants:

$$y = [1 - (cos\frac{\pi x^{2.32}}{2})]^{3.01} \tag{4.16}$$

where y and x are as previously defined. The main problem with this and other equations found in the literature but not discussed here, is that they either apply to very specific types of projects, or their functional form is such that it would be computationally difficult to estimate the model parameters.

For routine and widespread application to construction, it would be necessary that the parameters in the equation used be easily estimated and incorporated into computer spreadsheet packages. This is necessary because of the widespread use of spreadsheets in the industry (Mir, 1985). Since polynomial regression is applicable to all types of S-curves, and thus all forms of construction, and polynomial regression equation parameters can be obtained using spreadsheet packages like Lotus 123, Quattro or VP Planner; it is the most suitable for routine application.

4.5 Examination of the use of polynomial regression

The above outline and the literature reviewed indicates that polynomial regression would be the best method to use in modelling the cumulative expenditure profile of a given construction project. Polynomial regression is therefore examined in more detail to demonstrate its application, its accuracy and any possible limitations when used for escalation computation. This is done by applying the polynomial regression method to some completed project data.

4.5.1 Description of data used for analysis

Past cost data on four hospital projects constructed and completed within the last ten years in Newfoundland were used. The total construction cost and time for the projects are listed in Table 4.2.

The client for all four hospital construction projects was the Government of Newfoundland and Labrador, Department of Public Works and Transportation. All projects had different contractors and project consultants. The data used for this analysis was obtained from the clients copies of the various project payment certificates.

The total cost and time shown in Table 4.2 is the cost and time to substantial completion and not practical completion. This is because for all these projects, there were varying and significant time lags between substantial and final completion. During this period a lot of change order (variation) works were executed. This period of execution of variation works is not required for estimation of escalation costs prior to construction because escalation at

Table 4.2: Total project cost and time for four hospital projects (DPWT,1990)

Hospital Project	Total cost in Dollars	Construction time in months
1	13,330,000	26
2	11,600,000	24
3	3,200,000	14
4	6,000,000	26

the beginning of a project is estimated only for works to be executed that are covered within the original contract sum.

Unlike the other three projects, project 1 was started a month before the holiday and winter month of December in which relatively little work was done. For analytical and comparison purposes, normalizing as discussed in Section 4.4.3 is necessary and therefore an adjustment has been made to correct this anomaly. This adjustment is combining the second and third months work on this project and representing the work executed in these two months as one months work thus reducing the construction time by one month to the time shown in Table 4.2. The original data extracted from the clients copies of the payment certificates before any of the above adjustments were made is listed in Appendix C.

4.5.2 Application of regression analysis

The value of the monthly work completed for each project was extracted from the payment certificates. The cumulative value of the work completed for a construction project is normally proportional to the cumulative expenditure. As such, a method which models the work executed will also model the cumulative expenditure (Carr et al, 1974). Regression analysis was performed on this data using LOTUS 123 (TM) to find equations which would model the cumulative value of work executed for each project. Third order solutions of the S-curves for each project were obtained of the form:

$$y = a + bx + cx^2 + dx^3 \tag{4.17}$$

Where x is the percentage of total planned completion time, y is the value of work executed expressed as a percentage of the total estimated contract work value and a,b,c and d are parameters (constants) estimated by the regression analysis.

A summary of the results of the regression analysis are given in Table 4.3. A listing of the adjusted data used and the computer printout of this analysis are given in Appendix D secion D.1.

All the regression equations explain over 99% of the variation of percentage cost with time as indicated by the R-squared statistic value of over 0.99 shown in Table 4.3. For all equations, the coefficients b, c and d were significant at the 99% confidence level as evident from absolute coefficient values of more than three times the magnitude of the standard error of the coefficients. LOTUS 123 does not provide an estimate of the standard error of the constant term, coefficient a.

The purpose of the analysis was to examine the accuracy of the regression

Table 4.3: Summary of regression analysis results

Hospital Project	1	2	3	4
Value of coefficient a	-3.28027	-4.02075	2.877277	3.562784
Coefficient b:				
Value	1.082935	1.353455	0.902173	0.801184
Standard error	0.126195	0.142113	0.189750	0.112559
Coefficient c:				
Value	0.111149	0.007714	0.013598	0.014197
Standard error	0.002964	0.003342	0.004503	0.002677
Coefficient d:				
Value	-0.00011	-0.0011	-0.011	-0.0012
Standard error	0.000019	0.000021	0.000029	0.000017
R-squared value of regression output	0.996746	0.996178	0.995687	0.997107

analysis output in estimating escalation, and therefore no further analysis of the regression output statistics was deemed necessary. In order to quantify with any reasonable degree of accuracy the range in which the various coefficients would be expected to lie for hospital projects in Newfoundland, a much larger sample space (that is, a much larger number of hospital projects) would be necessary. This is presently not possible due to the small number of hospitals that have been built in the province over the last ten years.

4.5.3 Accuracy of regression models

The fit of the regression equation and actual values of the plots of percentage value against percentage time are given in Figure 4.6. The percent time is the time at any given point expressed as a percentage of total project construction time and the percent value is the construction costs at any given point expressed as a percentage of total hospital construction costs. The total hospital construction times and costs which were obtained as previously discussed are given in Table 4.2.

The regression models automatically give smoothed representations of the actual plots. Figure 4.6 shows that although the regression models fit the actual plots quite well they tend to be inaccurate towards the end of the curves. Since it is known before execution of any project that 100% value of work complete corresponds to 100% time, a correction for this is required when using the equations to forecast.

To test the accuracy of these equations when used to forecast cost escalation, each hospitals cash flow was forecasted using the equations derived from the adjusted data of the other three hospitals. This is done to simulate the estimating situation found in practice where the actual cash flows of the

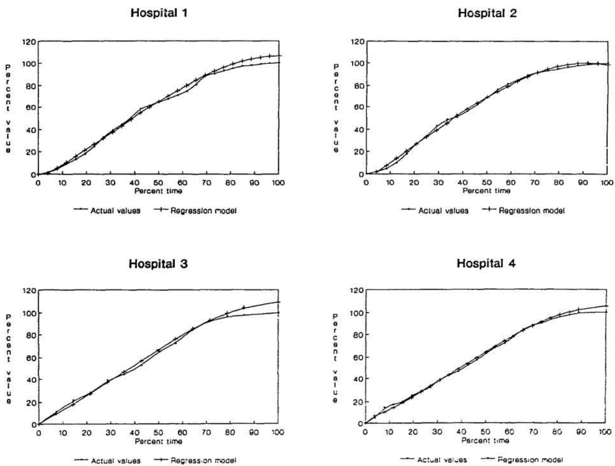


Figure 4.6: Regression model fit to actual values

project at hand is unavailable but similar completed projects cash flows can be obtained.

The same annual escalation rate was applied to all forecasted and actual hospital construction cash flows. The amount of escalation calculated when this rate is applied to the actual projects cumulative cash flow was compared to that obtained when this escalation rate is applied to the projects cumulative cash flow estimated using regression equations from the other three projects.

When applying the regression equations, values obtained towards the end of the projects greater than 100% were adjusted to 100%. This was done to eliminate some of the end inaccuracies previously discussed. Spreadsheets were used to test the accuracy of estimating each hospitals escalation costs using cash flows obtained from applying the regression equations of the other three hospitals. Computer printouts of these spreadsheets are given in Appendix D section D.2. A summary of the results obtained are given in Table 4.4.

A hypothetical annual escalation rate of 10% was used to obtain the results shown in Table 4.4. The escalation estimate using actual cash flows shown in Table 4.4 is the amount of escalation computed using the value of work executed as obtained from the payment certificates. This is compared to the amount of escalation computed using the estimated value of work as obtained by applying the regression equations from other hospital data. The percentage error measures the difference between the escalation computed from the actual cash flow and that from a given regression equation .

The percentage error was found to range from 0.33% to 8.57% with an average value of 4.17%. The amount of escalation is directly proportional to

Table 4.4: Results of escalation computation using various models

Hospital Project	1	2	3	4
Escalation estimate using actual cash-flow values	\$1,205,845	\$898,310	\$141,585	\$528,626
Escalation estimate using Hospital 1 regression equation	Not	\$937,508	\$145,939	\$526,906
(Percentage error)	Applicable	(4.36%)	(3.08%)	(0.33%)
Escalation estimate using Hospital 2 regression equation	\$1,102,960	Not	\$138,118	\$498,250
(Percentage error)	(8.53%)	applicable	(2.45%)	(5.75%)
Escalation estimate using Hospital 3 regression equation	\$1,102,557	\$886,058	Not	\$498,025
(Percentage error)	(8.57%)	(1.36%)	applicable	(5.79%)
Escalation estimate using Hospital 4 regression equation	\$1,154,620	\$928,167	\$144,687	Not
(Percentage error)	(4.25%)	(3.32%)	(2.19%)	applicable

Average percentage error = 4.17%

the applied escalation rate. As a result, the computed percentage error would not change with varying escalation rates. Therefore the expected percentage error using this method from the data analyzed is approximately 4% for any assumed or applied escalation rates.

4.6 Usefulness and limitations of polynomial regression models

A detailed construction estimate, which is the most thorough, exhaustive and accurate method of estimating costs for a project, has an expected percentage error of 5% (Ahuja and Campbell, 1988). From the results of the data analyzed, the expected percentage error of polynomial regression of less than 5% indicates that use of polynomial regression equations to estimate contract cash flow for escalation computation purposes has an accuracy consistent with the accuracy required for detailed cost estimates. Polynomial regression can therefore be used for escalation estimation purposes for any kind of estimate be it preliminary, elemental, unit price or detailed.

Parsimony dictates that a more complicated or detailed method be used for estimating only if it undoubtedly provides better estimates than a simpler method. This is due to limits of available data and the frequent necessity of obtaining estimates in the shortest possible time. Since the accuracy of polynomial regression models has been shown to be consistent with the accuracy required for a detailed construction cost estimate, use of detailed schedules cannot be undoubtedly more accurate. Polynomial regression models are therefore recommended for estimating the expenditure cash flow of construction projects for escalation computation purposes if required completed project cost flow profiles are available.

Organizations that have been involved and expect to continue to be involved in the construction of a large number of construction projects of a particular type can apply polynomial regression to their historical costs and obtain the range within which the various parameters of the polynomial regression equations are expected to be. With this information, the organizations would be able to estimate the cumulative cost flow of future similar projects for escalation computation purposes without having to analyze historical costs in order to obtain the required S-curve.

The main limitation in the use of polynomial regression is the requirement of historical cost flow data. This data may not be available especially for unique one of a kind projects, for example, as may occur in renovation works.

It should be noted that though the accuracy with which polynomial regression models model a projects cash flow for escalation computation purposes is consistent with the accuracy required for detailed cost estimates, the resulting escalation forecast is not necessarily as accurate. Inaccuracies in estimating escalation costs will be compounded by inaccurate forecasts of the cost indices measuring the level of escalation and any inaccuracies in the representation of actual construction costs by the cost indices.

Chapter 5

USE OF ESCALATION CLAUSES

5.1 Introduction

From a review and application of various forecasting methods, it was concluded in Chapter 3 that quantitative forecasts of cost escalation do not eliminate the risk caused by cost escalation due to the unpredictability of some of the causes of cost escalation. Construction cost escalation still remains a risk to be managed by the parties to a construction contract in spite of all available forecasting methods.

Mason (1973) formulates four general methods for managing risk. The four general risk management methods are: risk avoidance, risk abatement, risk transfer, and risk retention.

Risk avoidance entails avoiding the activity with which the risk is associated. Construction cost escalation risk cannot be avoided because it is inherent in the construction process.

Risk abatement involves loss prevention and reduction to lower the chance of loss occurrence and to diminish the severity of loss, should it occur. The risk of cost escalation may be somewhat abated by prepayment or use of mobilization payments. Prepayment or use of mobilization payments does not eliminate escalation risk because not all construction costs can be incurred in a lump sum at the beginning of the project. Furthermore, large mobilization payments increase the interest during construction paid by the owner. The use of mobilization payments thus partly transforms the problem from that of risk due to cost escalation to uncertainty in the amount of interest paid during construction. Hence, this does not effectively solve the problem. There is need for further research into prepayments ability to minimize the combined cost of escalation and interest during construction. This is, however, not within the scope of this thesis and therefore will not be addressed herein.

By exclusion, the only remaining methods to manage escalation risk are by risk transfer or risk retention. Risk transfer involves shifting the risk burden from one party to another and risk retention is not transferring the risk. The owner or his agent decides whether or not to bear the risk of cost escalation when selecting construction contract provisions assigning risk. As Erickson and O'Connor (1979) put it, construction "risks are managed primarily by assigning them to one or more of the parties to the construction process." Risk transfer and risk retention are effected by the use of escalation clauses. This chapter examines the use of escalation clauses in allocating escalation risk.

5.2 Merits of various risk allocation policies

5.2.1 Advantages of owner bearing escalation risk

One of the main disadvantages of the contractor bearing the risk of escalation as Stukhart (1982) states, is "the owner will be paying contingency costs that may be more than they are really worth to the owner because the contractors contingency reflects a different utility function from the owners." Other disadvantages of the contractor assuming the risk of escalation are:

1. The contractor includes a contingency figure to cover the possibility of loss. The contractor, however, usually resorts to litigation with its attendant delay and legal costs to the owner in the event the amount included in the contract sum proves inadequate (ASCE., 1979). The contractor may also attempt to recoup losses through substandard work or substitution with cheaper materials.
2. Competition when bidding may be reduced because financially secure or reputable contractors may not bid expecting to be undercut by risk taking contractors or contractors who are not fully aware of the risks (Carr, 1977) or contractors who inadequately appraise the cost of escalation involved.
3. If the owner is government, or any other large organization the owner may have access to better information than the contractor and therefore be in a better position to more accurately forecast escalation costs (Stukhart, 1982).
4. The owner still has to pay the amount included in the contractors bid to cover escalation even when the amount of escalation is less than predicted (Stukhart, 1982)
5. Though the contractor may reap a windfall if predicted costs turn out lower, he may not be in a financial position to cover costs in the case of higher than predicted costs. As Carr (1977) puts it "the owner is left holding the bag". In this case, "the contingency paid by the owner is not justified" (Erickson et al, 1978).
6. As Erickson and O'Connor (1979) assert, when a contractor must assume risk, smaller contractors who are otherwise technically competent and competitive may not be in a financial position to bid competitively without exposing themselves to the possibility of catastrophic loss. However, if the owner assumes the risk, smaller competent contractors may bid and increase competition.
7. The owner wishes to get a job well done and have a good contractor available for future work (ASCE, 1979). If costs turn out unexpectedly high, however, the otherwise good contractor could go bankrupt and be unavailable for future work.

The above outlined disadvantages of the contractor bearing the risk of escalation are the principle reasons why measures are sought to transfer the risk of cost escalation from the contractor to the owner. The author recommends use of escalation clauses to avoid these disadvantages if the disadvantages of the owner bearing the risk of cost escalation can be obviated.

5.2.2 Disadvantages of owner bearing escalation risk

There are a number of disadvantages in the owner bearing the risk of escalation. The risk of escalation is transferred from the contractor to the owner by use of escalation clauses. The disadvantages of using escalation clauses are:

1. The owner for various financial or political reasons may need to have a firm or fixed final cost (Levitt et al., 1980) which is not possible when escalation clauses are incorporated in a contract.
2. Detailed escalation clauses are required to effectively account for escalation, and these may be difficult or expensive to structure, develop and maintain (Erickson et al, 1978).
3. Monitoring, inspection and approval of claims submitted by the contractor to the owner for escalation costs will increase administrative costs (Stukhart, 1982).
4. The escalation clause may not accurately compensate for the amount of escalation (Warszawski, 1982b).
5. The contractor may not perceive that his risks have been significantly reduced, and therefore may not sufficiently decrease the amount of contingency included in his bid (Erickson et al, 1978).
6. The contractor will have a reduced incentive to control or keep costs down (Erickson et al, 1978). This may induce cost escalation.

For these reasons, escalation clauses are not incorporated in all contracts. Many of these disadvantages can be obviated by the use of properly structured escalation clauses. Cost escalation is not the sole cause of price uncertainty at a contracts prebidding stage and therefore use of escalation clauses should not deter an owner from starting a construction job due to financial reasons. The owner should set up a contingency fund, not included in the contractors contract sum, to cover cost escalation and other reasons for price change such as design inadequacies, change orders, and unforeseen changes after tender award. Escalation clauses should be used wherever the particular conditions of a given construction project warrant.

5.3 Guidelines for the use of escalation clauses

The guidelines to follow when considering whether or not to use escalation clauses can be summarized as follows:

1. An escalation clause may not be required for a project with a duration of less than one to two years if a predictable and small escalation rate is foreseen (ASCE, 1979).
2. The individual risk preferences of both the owner and the contractor should be examined (Warzawski, 1982b). In cases where the owner is risk neutral and the contractor is risk averse, means of transferring the risk of cost escalation to the owner should be sought.
3. The risk of cost escalation should wherever possible rest with the party that can best control or influence it. For example, if the contractor is able to control labour costs through labour agreements, then the contractor should bear the risk of escalating labour costs. If the contractor is unable to control or influence any component of cost escalation, then the risk involving that component should remain with the owner.
4. The risk of escalation should be borne by a party that is financially able to bear the costs of the worst possible outcome (Erickson et al, 1978).
5. Consideration should be given to the administrative cost of processing claims for cost escalation. Escalation clauses which are expensive to administer should be avoided.

Generally, other than in short projects expected to be built in stable conditions, some or all the risk of cost escalation should be transferred to the owner using properly structured and efficient escalation clauses.

5.4 Required attributes of escalation clauses

Many of the disadvantages discussed for using escalation clauses can be overcome by properly structuring the escalation clause. The required attributes of escalation clauses necessary to overcome most of the disadvantages have been summarized by Fellows (1984) as follows:

1. "accuracy of recompense and fairness between the parties"
2. "simplicity, clarity and low cost of operation"
3. "compensation for, but not inducement of" escalation.

Not all the methods of price adjustment or escalation clauses available satisfy the above criteria.

5.5 Price adjustment methods

The methods by which certain contracts allow for adjusting the contract price to recompense for escalation can be generally classified into three categories namely: the cost-plus method, the British traditional fluctuation method, and formula escalation.

5.5.1 Cost-plus method

The cost-plus method is the method of price adjustment used in cost-plus-fee types of contracts where the owner is contractually obliged to reimburse the contractor for all costs incurred in execution of the contract including escalation costs (Peurifoy and Ledbetter, 1985). The cost-plus method, albeit simple, clear and accurate, offers no incentive to the contractor to keep down costs. It can therefore be an inducement for escalation. Furthermore, it requires a lot of documentation on the part of the contractor and verification on the part of the owner, which makes it expensive to operate. Use of the cost-plus method solely as a means of managing escalation should therefore be avoided.

5.5.2 British traditional fluctuation method

In the British traditional fluctuation method, the contract specifies that certain increases in costs over base costs included in the contract be reimbursed (Fellows, 1984). The net difference between the costs at the time of valuation and the base costs included in the contract is recoverable by the contractor for specific items.

The British traditional fluctuation method is simple and clear but does not accurately recompense for cost escalation. This is because only increases in the costs of the items specified in the contract and not all increases in cost are reimbursed.

In the British traditional fluctuation method, the contractor has to present wage sheets and invoices with his claims. These supporting documents include not only the contractors own documents which would be easy to obtain but also proprietary documentation from the contractors subcontractors which would be more difficult for the contractor to collect. A general contractor who uses the services of several subcontractors would therefore find difficulty in claiming for reimbursement for escalation under the British traditional fluctuation method

In the use of this method, the contractors incentive to keep costs down for the basic escalation recompensable items is reduced. If the number of recompensable items is great, the traditional method is expensive to administer for both the contractor who submits the claims and the owner who has to verify them.

5.5.3 Formula escalation

Formula escalation is used when a formula usually incorporating indices, is written into the contract (ENR, 1989). The contract price is adjusted by an amount calculated using the formula which depends on the change in the formula inputs.

In the use of formula escalation, the contractor does not have to substantiate his basic prices at the time of entering the contract. The contractor also does not have to produce his own or his subcontractors invoices when making claims. The amount of verification by the owner is reduced and this reduces administrative costs.

With formula escalation, if the contractor buys well (that is, if he improves on the quotations for construction elements which he obtained at tender stage), he will not have to pass on to the employer the benefits of his improved buying policy. As a result, the contractor still has incentives to keep costs down and therefore formula escalation does not induce escalation.

The accuracy of formula escalation depends on the manner in which the formula is structured and applied (Fellows, 1984). Formula escalation is simple, clear, predictable and inexpensive to administer. Of all methods of price adjustment, formula escalation is the best method to use in escalation clauses provided the formulae are properly structured and applied.

5.6 Application of formula escalation

An insight into the way formula escalation is structured and applied can be obtained by examining typical formulae used for computing escalation. One example of the formulae typically used to compute escalation is the formula used in Kpong Hydroelectric Project, Ghana which was of the form (Acres, 1977):

$$\delta_e = 0.85\Delta \sum_{i=1}^{8} a_i \frac{C_{ai}}{C_{oi}} \tag{5.1}$$

Where:

δ_e = Adjustment due to escalation.

Δ = Total unadjusted value of work executed.

a_i = Weight of commodity i.

C_{ai} = Cost index of commodity i at time of valuation.

C_{oi} = Cost index of commodity i at date of tender.

This formula was intended to compute escalation in foreign material and labour costs and was based on the main commodities contributing to these costs. Eight commodities were included in the formula, namely: cement, steel, tires, explosives, plant, salaries, shipping and miscellaneous products. In using this formula, predetermined independently published indices for each of these eight commodities were used in the computation of the adjustment due to escalation. The factor 0.85 was used in the formula so as to exclude the contractors profit and certain overhead items from the escalation cost computations.

This formula was found to work quite well throughout most of the project. As the project neared completion, however, it was found that inaccuracies occurred in the application of this formula. For example, increases in, the cost of explosives would cause the same increase in escalation costs regardless of whether a large amount or a relatively small amount of explosives were used for a given amount of measured work. This inaccuracy was due to the fixed weighting used for the various commodities provided related commodities were used since the time of the last interim valuation. Such inaccuracy is bound to occur in formulae structured in this manner and has to be avoided.

Another example of formulae typically used to compute escalation is the NEDO formula for price adjustment in use in Britain (Shaw, 1974). In Britain, the National Economic Development Office (NEDO) introduced their first formula series for adjustment of fluctuations in respect of building works in June 1974. These series divide the total building contract works as measured in the Bills of Quantities into a number of work categories. For each category an index is published monthly for use with the formula. The increase or decrease in a given period is calculated by summing up the increases or decreases of all work categories. The way in which increases or decreases is computed for each work category is exemplified in Table 5.1 which uses the work category and index for substructure works.

With formulae structured like the NEDO formula, the amount of reimbursement due to escalation for a particular category is proportional to the amount of work executed in that category. The inaccuracy discussed in formulae structured as the formula given in Equation 5.1 with fixed category weightings is therefore avoided.

Fellows (1984) describes some inaccuracies in the use of the NEDO formula for escalation reimbursement in Britain. These inaccuracies are mainly due to not having all resources accurately represented by the indices used, and also due to formulae in use in Britain using national indices which are average in character thus not reflecting local factors and project individual characteristics.

These inaccuracies are mainly due to the indices used and are not due to

Table 5.1: Example of application of NEDO Formula Method

SUBSTRUCTURE WORKS
-Calculation of Effect of Escalation

A. Values of Cost Index for substructure Works

		Index
At base date	March 1989	136.0-basic
At dates of valuations	April 1989	137.6
	May 1989	135.0
	June 1989	140.0
	July 1989	144.0
	August 1989	147.0
	September 1989	150.0

B. Effect of Escalation

Valuation	Period covered	Amount in Pounds	Price Index	Increase or decrease over Basic	Increase in Pounds	Decrease in Pounds
1	14.4.89 to 10.5.89	25,000	137.6	$\frac{1.6}{136.0}$	294	-
2	11.5.89 to 14.6.89	35,000	135.0	$\frac{1.0}{136.0}$	-	257
3	15.6.89 to 10.7.89	15,000	140.04	$\frac{4.0}{136.0}$	441	-
4	11.7.89 to 12.8.89	10,000	144.0	$\frac{8.0}{136.0}$	588	-
5	13.8.89 to 10.9.89	7,500	147.0	$\frac{11.0}{136.0}$	606	-
6	11.9.89 to 5.10.89	5,000	150	$\frac{14.0}{136.0}$	514	-
	Totals to date	97,500			2443	257

the formulae *per se*. These inaccuracies can therefore be abated by the use of more representative indices. The formulation and structure of appropriate cost indices is discussed in the next chapter.

Bills of Quantities as part of the contract documents and regularly published relevant indices are a prerequisite for the use of formula escalation. Properly structured formula escalation using the NEDO type of formulae is the best method to use in escalation clauses.

Chapter 6

DISCUSSION OF RECOMMENDED METHODS

Various alternate methods available to quantify construction cost escalation have been reviewed in the preceding chapters. Suitable methods have been recommended from the available alternatives. The attributes of the recommended methods have been demonstrated using case studies and other examples. The general procedure followed in applying the recommended methods has been outlined. The main purpose for the use of case studies and other examples has been to illustrate the benefits and limitations of the recommended methods. As a result, some criteria and procedural steps used in applying these methods, in particular, the use of cost indices, may not be obvious. This chapter discusses elements of procedure and some criteria that should be used in applying the recommended methods of quantifying cost escalation which were not specifically addressed in the preceding chapters, in particular, the use of cost indices.

6.1 Reasons for quantifying escalation

The amount of escalation has to be quantified for two principle purposes namely:

1. To forecast the amount of escalation prior to the execution of a construction contract. The owner and project consultants require forecasts of the amount of escalation for budgetary and planning purposes. The contractor mainly requires a forecast of the amount of escalation at the bidding stage of a contract.
2. During execution and after completion of a project, the amount of escalation has to be quantified in order to track its effect on the contract and to adjust the contract sum to cover cost escalation if escalation clauses are used.

For both these purposes, the methods recommended in the preceding chapters all measure the level of cost escalation using cost indices. In forecasting construction cost escalation, the values of an appropriate cost index have to be forecast. In tracking or adjusting the contract sum for increases in costs, use of a formula based on cost indices has been recommended. As such, it is essential in quantifying escalation for any of the above purposes to obtain data on appropriate construction cost indices. An understanding of cost indices is therefore a prerequisite to proper use of the methods recommended for quantifying escalation.

6.2 Cost indices

A cost index is a ratio of the cost of a resource or composite of resource costs at one period of time, and the cost of the same resource or composite at a specific previous date or period called the base period. The cost index indicates the percent change in cost that has resulted from escalation between the base period and the later date. Cost indices are mainly used for the following purposes:

1. To obtain new estimates from historical data (Ahuja and Campbell 1988).
2. For property valuation (ENR 1989)
3. To provide for contract escalation (Ahuja and Campbell 1988)
4. To serve as historical data for future projects.

6.2.1 Classification of indices

Indices can be classified according to the manner in which they treat the weights of the various components (Wonnacott and Wonnacott, 1984). The most common type of indices are the Laspeyres type in which the weights are fixed and determined by the initial component mix. Another type of index is the Paasche type in which the weights of the components vary. This index is based on the later and not the initial component mix. The geometric mean of a Laspeyres and Paasche index is called a Fisher index. Indices in which the base year changes are called Chain indices. The formulation, sources and examples of indices appropriate to construction are given in the sections of this chapter that follow.

For purposes of computing the amount of construction cost escalation, one is interested in the change in the cost of construction elements when compared to the initial cost of elements in the original contract sum. Therefore, Laspeyres type of indices, in which the weights are fixed and determined by the initial component mix, are most appropriate for use in quantifying construction cost escalation.

6.2.2 Index formulation

Laspeyres type of cost indices are generally formulated as follows (Ahuja and Campbell 1988):

$$I_t = \sum_{i=1}^{n} W_i(P_{t0})_i \qquad (6.1)$$

where:

$I_t =$ price index at time t.
$(P_{to})_i =$ ratio of prices of commodity i between the time base period 0 and period t.
$W_i =$ weight or relative importance of commodity i, $i = 1$ to n

A summary of the information required to develop the weights of a construction cost index is illustrated in Table 6.1 (Public Works Canada, 1989, reproduced with the permission of the Minister of Supply and Services Canada, 1990). Table 6.1 depicts the construction element breakdown of a typical new road construction with all costs expressed as a percentage of total element or construction costs. The index for new road construction could be based on the costs of the five main elements: clearing, drainage, subgrade, surfacing and miscellaneous. Each element could also be divided into its components of labour, equipment and material as shown in Table 6.1. An index could be developed for each element and a composite index for new road construction formed as a combination of the element indices combined using the weights indicated.

6.2.3 Sources of indices

There are a multitude of indices published by various sources at regular intervals. One of the better known sources of construction cost indices in North America is the *Engineering News Record* (ENR). The ENR publishes selected material, labour and plant indices for both individual elements or

Table 6.1: Construction element breakdown of typical new road construction (from Public Works Canada, 1989, Reproduced with the permission of the Minister of Supply and Services Canada, 1990).

ELEMENT	WEIGHT %	Labour %	Equipment %	Material %	Total %
Clearing	4	35	65	-	100
Drainage	5	40	20	40	100
Subgrade:					100
-Earthwork	15	30	70	-	100
-Borrow	40	30	70	-	100
-Rock	10	35	65	-	100
Surfacing					
-Hot mix	16	25	45	30	100
Miscellaneous	10	40	40	20	100
TOTAL	100				

inputs and composites. Two monthly published composite indices are the Building Cost Index (BCI) and the Construction Cost Index (CCI). The BCI and the CCI are Laspeyres type composite indices representing twenty U.S. cities average hourly wage rate for common labour, mill price of steel shapes, price of portland cement and lumber. The two indices differ in the weights given to the various components and the make up of the costs of the labour component. A detailed description of these indices, their history, formulation and use can be found in ENR (1989). The CCI and the BCI may not adequately reflect escalation of construction costs for some construction projects because the mix of resources only partially reflects the mix in any construction project and because plant costs have been excluded.

The BCI and CCI are general purpose indices since they are not prepared for a specific type of construction project or a specific element of construction. In most cases, general purpose indices will be found to be too general for use in determining the effect of escalation on a particular project. Specific indices prepared for a particular construction project type or construction element, with selected resources to represent the types of resources used in the project or element, are necessary for effective determination of the effect of escalation. An important source of specific construction cost indices in Canada is Statistic Canada.

Statistics Canada publishes monthly in its Catalogue 62-007 (Statistics Canada, 1990), a number of specific indices— specific in the sense that the indices are prepared for specific types of construction projects or particular construction elements. The indices published by Statistics Canada will, in general, be useful in forecasting construction cost escalation (as demonstrated in the examples given in Chapter 3) but can be found to have some shortcomings if used for price adjustment in escalation clauses or for monitoring the effect of escalation on a specific project. The main possible shortcomings in the use of these indices are:

1. There may be a time lag of up to four months between the time that cost escalation is experienced and the time relevant indices are published by Statistics Canada and available to the general public.
2. Some indices appropriate to specific types of construction projects or elements of construction are published quarterly or annually, whereas escalation tracking and price adjustment will normally be required at least monthly during the execution of a given construction project.

Among the many other indices available in North America are the Boeck building cost index published by E.H. Boeck Co., and Means City Cost Index published by R.S. Means Co. The method of formulation and the frequency of publication of any index should be examined before use is made of any index in forecasting and tracking the effects of cost escalation. Large organizations, both private and public, involved in construction would benefit from maintaining cost indices specific to their type of construction for purposes of quantifying escalation.

Parsimony should be exercised in developing and maintaining cost indices. This means that the minimum number of indices each with the minimum number of weighted commodities and categories should be used consistent with the required accuracy. The indices should be kept as simple as possible to enable swift and timely computation.

6.3 Forecasting the amount of escalation

In chapters 3 and 4 it is recommended that the amount of escalation for a given construction project be forecast by initially forecasting the values of an appropriate cost index. From the forecasted values of the cost indices, the rate of escalation is then obtained and applied to the cash flow projections of the construction project generated by an appropriate cost flow model based on regression analysis. Further to the preceding discussion on cost indices, it is necessary to clarify the following with regard to forecasting the amount of escalation:

1. The cost index and the cost flow model used need not be for the entire construction project. Indices and cost flow models for various elements, work categories or trades associated with the construction project may be used to forecast the amount of escalation in the various elements, work categories or trades. The escalation amount for the whole project is then obtained by summing up the amount of escalation in all the various elements, work categories or trades.
2. Cost flow models can be developed for the construction activities, elements or trades using polynomial regression in the same way as described in Chapter 4 regarding the models which are developed for the entire construction project. Published results by Carr et al. (1974), Singh (1984) and Christian and Kakouris (1990) document the use of cost-flow models in modelling the cumulative cost flow of particular construction activities.
3. If a published index is used in forecasting escalation instead of an index developed and maintained by the organization doing the forecasting, then the historical change in the published cost index should be examined and compared with the historical change in the costs of the construction project type, element, work category or activity. This is to ensure that the index properly reflects the change in costs being forecast.

6.4 Escalation tracking and price adjustment

In Chapter 5 it is recommended that in order to track the amount of escalation during construction and to adjust the contract sum to cover escalation costs to the contractor, a formula based on indices for the various work categories be used. Further to the preceding discussion on cost indices, it should be noted that the indices developed and maintained for use in formula escalation need not include all the items which contribute to the cost of a given element. Twenty percent (20%) of the items of most cost estimates contribute eighty percent (80%) of the total costs (Ahuja and Campbell, 1988) and many construction elements escalate at similar rates. Therefore, use of indices which adequately represent the rate of cost increase of the major cost items for a given construction project will suffice for most escalation computation purposes.

It should also be noted that indices used in any escalation clause should be published by an independent body. Any dealings between the parties to the contract and the independent body should be at arms-length. The independent body publishing the indices should be contacted prior to the contract to determine if there are any upcoming major revisions which are likely to affect the indices selected. The producing agency should be asked to notify the parties to the contract if the selected indices are about to undergo any major alterations.

6.5 Escalation treatment in the third world

In most countries of the third world, there exists a dearth of indices appropriate for the treatment of construction cost escalation. As a result, the methods recommended herein for the treatment of escalation cannot be easily applied.

There is, however, dire need for rational treatment of escalation given the high, double digit, fluctuating escalation rates experienced in such countries. For example, in Mexico, the level of inflation was 59% in 1982, approximately 80% in 1983 and approximately 60% in 1984. These high levels of inflation were reflected in the continual increase in the prices of materials, labour and equipment and drastically affected the construction industry there (De La

Garza and Melin, 1986).

In Uganda, whose conditions the author is familiar with, there are hardly any construction cost indices available let alone regularly published. Very high rates of escalation are experienced but are not properly documented by government authorities. The Government of Uganda, which is the nations largest initiator of construction projects, still uses the British traditional fluctuation method in contracts where escalation clauses are utilized. In Uganda, and in other countries with similar conditions, the effect of escalation could be ameliorated if an appropriate agency regularly published relevant cost indices and if a formula method, similar to the NEDO formula discussed in Chapter 5, were adapted.

Chapter 7

SUMMARY AND CONCLUSIONS

Amounts allowed for escalation of construction costs account for a substantial part of many construction project cost estimates. Drastically changing escalation rates can have adverse effects on the financial success of these projects.

Escalation can be caused by a variety of factors some of which include inflation, changing market conditions, changing tax rates, schedule alterations, contract risk allocation, and major events such as the outbreak of war. Some of these factors are by their very nature unpredictable. As such, the main effect of escalation is that it causes risk and uncertainty regarding a project's costs.

The amount paid to cover escalation by an owner of a construction project will depend on the attitude towards risk of the party to the construction contract that bears the risk of cost escalation. An assessment of this amount under various risk allocation scenarios can best be arrived at using the concept of expected utility value. From a purely expected utility value point of view, financially stable contractors (who are normally risk averse) will include in their prices more than the cost which the owner (who is more likely to be risk neutral) would be willing to pay for the same risk.

A forecast of the amount of escalation is required for budgetary and bidding purposes. To forecast the amount of escalation for a given construction project, it is necessary to forecast the applicable escalation rate (measured by means of cost indices) and apply this rate to the estimated expenditure cash flow. With the availability of user friendly forecasting software, many complex statistical forecasting techniques can now be used to forecast construction cost escalation rates. This can be done provided the practitioner can interpret the results produced by these software packages.

The statistical techniques used and applicable to construction cost indices are either univariate or multivariate methods. Univariate time series methods are based on the assumption that existing patterns in the data will continue. They therefore will not usually predict turning points or changes in trend since they assume existing trends will continue. Univariate methods are not recommended if there is reason to believe existing conditions will change dramatically.

Multivariate forecasting methods are dependent on the accuracy of the explanatory variables used in the forecasts. One of the main difficulties in their use is the identification and acquisition of data on statistically significant explanatory variables. The accuracy of the multivariate forecasts produced depend on the accuracy of the explanatory variables used to make the forecasts.

The analytical forecasting techniques reviewed are only valid for short term forecasting. This is so because all analytical methods reviewed, both univariate and multivariate, are base on empirical relationships derived from historical data which can only be rationally assumed to hold in the short term. In the literature reviewed, no analytical forecasting technique has been found capable of forecasting cost indices for a construction project lasting two years or more.

The expenditure cash flow of a project to which the forecasted escalation rate is applied, can be estimated by use of either a planned progress schedule or a cost flow model. Use of a planned progress schedule to estimate a project expenditure cash flow requires a detailed breakdown of a contract's costs. This may not be possible in many estimating situations. Use of planned progress schedules are more involved computationally than the use of cost flow models. Published results indicate that detailed computation of costs from planned progress schedules do not necessarily give more accurate estimates than the use of cost flow models.

The use of cost flow models requires the availability of similar, past project's S-curve shaped cost flow profiles. Of the various cost flow models examined and from the literature reviewed, models based on polynomial regression were found to be the most versatile, in that they can be applied to construction projects with cash flow profiles that give any form of S-curve shape. The model parameters of a polynomial regression cost flow model can be estimated using readily available computer programs or spreadsheet software packages. Application of these models indicates that they have an accuracy consistent with the accuracy required for detailed estimates. Polynomial regression can therefore be used for escalation estimation purposes for any kind of estimate be it preliminary, elemental, unit price, or detailed.

Parsimony dictates that a more complicated or detailed method be used for estimating only if it undoubtedly provides better estimates than a simpler method. This is due to limits of available data and the frequent necessity of obtaining estimates in the shortest possible time. Since the accuracy of polynomial regression models has been shown to be consistent with the accuracy required for a detailed construction cost estimate, (which is the most thorough, exhaustive and accurate method of estimating costs for a project), use of detailed schedules, or any other models, cannot be undoubtedly more accurate. Polynomial regression models are therefore recommended for estimating the expenditure cash flow of construction projects for escalation computation purposes if required past project cost flow profiles are available.

Being able to give quantitative forecasts of escalation does not eliminate the risk caused by cost escalation. This is so because none of the discussed techniques can forecast escalation caused by unpredictable occurrences which include government action or major events like the outbreak of war. The analytical methods available are only useful in forecasting for short construction projects in stable conditions. Construction cost escalation, with or without the use of these forecasting methods, still remains a risk to be undertaken by either the contractor , the owner or both depending on the terms of the construction contract.

The effect of escalation can be minimized by carefully allocating the risk of escalation to the various contracting parties. Needless allocation of escalation risk to the contractor in accordance with the standard conditions of some contracts benefits neither the owner nor the contractor. Various factors should be considered in deciding which party bears the escalation risk.

Generally, other than in short construction projects to be built under stable conditions, means of transferring some or all the escalation risk to the owner should be sought. The best method to transfer escalation risk to the owner is by the use of an escalation clause incorporating a formula based on cost indices. The prerequisites for effective use of formula escalation are the inclusion of Bills of Quantities in the Contract Documents and the maintenance of regularly published relevant indices. Maintenance of regularly published indices would not only provide for contract cost escalation but would also be useful in updating past historical costs and in other estimating situations.

Prepayment or the use of mobilization payments can abate the effect of escalation but results into an increase in the cost of interest during construction. There is need for further research into prepayments ability to minimize the combined cost of escalation and interest during construction.

REFERENCES

Abraham, B. and Ledolter, J. (1983). *Statistical Methods for Forecasting*, John Wiley & Sons, New York, N.Y.

Acres International Ltd. and Shawinigan Engineering Co. (1977) *Conformed Contract Documents, Contract K-3 Civil Works*, Kpong Hydroelectric Project, Ghana, Vol. 1, Schedule No. 3B, pp. 1-5

Ahuja, H.N., and Campbell, W.J. (1988). *Estimating: from Concept to Completion*, Prentice-Hall, Inc., Englewood Cliffs, N.J., pp. 28-29.

ASCE, (1979).*Construction Risks and Liability Sharing Conference*, American Society of Civil Engineers, Scottsdale, Arizona, Vol. I & II.

BFS, (1988). *FORECAST PRO*, Business Forecast Systems, Inc., 68 Leonard Street, Belmont, MA 02178 USA.

Box, G.E.P. and Jenkins,G.M. (1976). *Time Series Analysis for Forecasting and Control*, Holden Day, San Fransisco.

Brophy, R. (1990), Department of Public Works and Transportation, St. Johns, Newfoundland, in lecture given to Term 8 Civil Engineering Class, Memorial University of Newfoundland, St. John's, Newfoundland, 23 February 1990.

BSC, (1986). *TIMELINE*, Breakthrough Software Corporation, 505 San Mariin Drive, Nevado, Califonia 94947.

Campbell, W.J. (1990). *Private Communication*, Memorial University of Newfoundland, St. John's, Newfoundland.

Carr, R.I. (1977). "Paying the Price for construction Risk," *Journal of the Construction Division*, ASCE, Vol. 103, No. CO1, Proc. Paper 12827, pp. 153-161.

Carr, R.I., Brightman, T.O. and Franklin, B.J.(1974). "Progress Model for Construction Activity," *Journal of the Construction Division*, ASCE, Vol. 100, No. CO1, Proc. Paper 10428, pp. 59-63.

Chatfield, C., (1975).*The Analysis of Time Series: Theory and Practice*, Chapman and Hall, London, U.K.

Christian, C. and Kallouris, G. (1990). "Cost-time characteristics in construction projects," *Canadian Society of Civil Engineer's Conference*, Hamilton, Ontario.

De La Garza, J.M. and Melin, J.W. (1986). "Prepayment ability to offset inflation," *Journal of Construction Engineering and Management*, ASCE Vol 112, No. 4, paper No. 21090, pp. 514-528.

DPWT, (1990). *Private Communication*, Department of Public Works and Transportation, Government of Newfoundland and Labrador, St. Johns, Newfoundland.

Drake, B.E. (1978). "A Mathematical Model for Expenditure forecasting Post Contract,"*Proceedings of the Second International Symposium on Organization and Management of Construction*, Vol. II, pp.163-183.

Erikson, C.A., O'Connor, M.J. and Boyer, L.T., (1978). "Construction Process Risk Allocation," *1978 Transactions of the American Association of Cost Engineers*, 22nd Annual Meeting, San Fransisco, California, pp. 202-208.

Erikson, C.A. and O'Connor, M.J. (1979). "Construction Contract Risk Assignment," *Construction Engineering Research Laboratory*, Technical Report P-101, p.18.

ENR, (1980). "Escalation Clauses Split AGC," *Engineering News Record*,April 3 1980, pp. 73-74.

ENR, (1989). "ENR indexes track costs over years,"*Engineering News Record*, March 23, 1989, pp. 52-63.

Fellows, R.F., (1984). "A study of cost escalation in the Building Industry,"*4th International Symposium on Organization and Management of Construction*, Waterloo, Ontario, Volume 3: Developing Countries Research, pp. 927-937

Firth, M., (1977).*Forecasting Methods in Business and Management*, Edward Arnold (Publishers) Ltd., London, U.K., 21 p.

Goodrich, R.L., (1989). *Applied Statistical Forecasting,* Business Forecast Systems, Inc., Belmont, MA.

Goodrich, R.L. and Stellwagen, E.A. (1987). *Forecast Pro Statistical Reference,* Business Forecast Systems, Inc., Belmont, MA.

Granger, C.W.T. and Newbold, P., (1977).*Forecasting Economic Time Series*, Academic Press, New York, NY.

Hanna, A.S. (1990). *Private Communication*, Memorial University of Newfoundland, St. John's, Newfoundland.

Hardie, G.M., (1981). *Construction Contracts and Specifications*. Reston Publishing Company, Inc., Reston, Virginia, 44p.

Harris R.B., (1978).*Precedence and Arrow Networking techniques for Construction*, John Wiley and Sons Inc., New York, NY.

Ibbs, W.C., and Ashley, D.B. (1987). "Impact of Various Construction Contract Clauses,"*Journal of Construction Engineering and Management*, ASCE Vol 113, No. 3, paper No. 21832, pp. 501-517.

Koppula S.D., (1981). "Forecasting Engineering Costs: Two Case Studies,"*Journal of the Construction Division*, ASCE, Vol. 107, No. CO4, Proc. Paper 16739, pp. 733-743.

Lazar B.E. and Getson P., (1977). "Forecasting Construction Costs with Commodity Futures,"*Journal of the Construction Division*, ASCE, Vol. 103, No. CO3, pp. 381-386.

Levitt R.E., Ashley D.B., and Logcher R.D., (1980). "Allocating Risk and Incentive in Construction,"*Journal of the Construction Division*, ASCE, Vol. 106, No. CO3, Proc. Paper 15710, pp. 297- 305.

Lye, L.M. (1990). *Private Communication*, Memorial University of Newfoundland, St. John's, Newfoundland.

Mahler, F. and Mazina, M. (1982). "Earned Value Reporting Earns its Keep," *Cost Engineering*, Vol. 24, No. 1, pp. 13-17

Mahmoud, E. (1984). "Accuracy in Forecasting: a Survey," *Journal of Forecasting*, Vol 3, pp. 139-159.

Mason, G.E. (1973)."A Quantitative Risk Management Approach to the Selection of Construction Contract Provisions," *Technical Report No. 173* (The Construction Institute, Department of Civil Engineers, Stanford University).

MC, (1985). *Microsoft Project*, Microsoft Corporation, 10700 Northupway, Box 97200, Bellevue, Wa 98009, USA.

Milne A.D., (1984). "Mathematical Manipulation of S-Curves," *1984 Transactions of the American Association of Cost Engineers*, 28th Annual Meeting, Montreal, Quebec, pp. D.3.1-D.3.6

Mir, S.U. (1985). "Utilization of Microcomputers in the Construction Industry," *M.Eng. Thesis* Memorial University of Newfoundland, St. John's, Newfoundland, Canada, 11p.

Myers, R.H. (1986). *Classical and Modern Regression with Applications*, PWS Publishers, Boston, Massachusetts.

Nelson, C.R., (1973).*Applied Time Series Analysis for Managerial Forecasting,* Holden-Day Inc., San Fransisco, pp. 1-2.

Olkin, I., Gleser, L. J., and Derman, C. (1980). *Probability Models and Applications*, Macmillan Publishing Co., Inc., New York, N.Y.

Oyamada H. and Yokoyama K.V., (1986). "A study of Cost Estimating relationships between plant cost and economic trend factors," *1986 Transactions of the American Association of Cost Engineers*, 30th Annual Meeting, Chicago, Illinois, pp M.2.1-D.2.5

Padrnos J.V., (1981), "The many facets of escalation," *1981 Transactions of the American Association of Cost Engineers,* 25th Annual Meeting, pp E.3.1-E.3.4

Peer S., (1982). "Application of cost-flow forecasting models," *Journal of the Construction Division*, ASCE, Vol. 108, No. CO2, Proc. Paper 17128, pp. 226-232.

Peurifoy, L.R., and Ledbetter, W.B., (1985). *Construction planning, equipment and methods,* 4th edition, McGraw-Hill Book Company, New York, NY.

Pindyck, R.S. and Rubinfeld, D.L.(1976). *Econometric Models and Economic Forecasts,* 2nd edition, McGraw-Hill Book Company, New York, NY.

PS, (1986). *PRIMAVERA PROJECT PLANNER*, Project Management and Control Software, Primavera Systems, Inc., Two Bala Plaza, Bala Cynwyd, PA, USA.

Public Works Canada, (1989). *Technical Services Cost Reference Manual, 1989*, DIAND Technical Services Branch, A & E Services, Public Works Canada, reproduced with the permission of the Minister of Supply and Services Canada, 1990.

Rapier, C.P. (1990). "How to Deal with Accuracy and Contingency," *1990 Transactions of the American Association of Cost Engineers*, 34th Annual Meeting, Boston, Massachussets, pp K.8.1-K.8.8.

Riggs, J.L., Rentz, W.F., Kahl, A.L., and West, T.M., (1986). *Engineering Economics*, McGraw-Hill Ryerson Ltd., Toronto, 351p.

Shaw, W.T. (1974). "The NEDO Formula for Adjustment of Fluctuations in Respect of Building Works," *The Quantity Surveyor*, December 1974, p.108.

Statistics Canada, (1990). *Construction price statistics, Catalogue 62-007*, Statistics Canada, Prices Division, Ottawa, Ont., Canada, Third quarter 1989, pp. 11, 16, 22, and 24, Third quarter 1986, pp. 11, 16, 22, and 24, reproduced with the permission of the Minister of Supply and Services Canada, 1990.

Stevenson, J.J., (1984). "Escalation modelling, forecasting and tracking," *1984 Transactions of the American Association of Cost Engineers*, 28th Annual Meeting, Montreal, Quebec, pp F.3.1-F.3.7.

Stukhart, G., (1982). "Inflation and the Construction Industry," *Journal of the Construction Division*, ASCE, Vol. 108, No. CO4, Proc. Paper 17511, pp. 546-562.

Suhanic G., (1986). "The Cost Control Banana," *1986 Transactions of the American Association of Cost Engineers*, 30th Annual Meeting, Chicago, Illinois, pp. B.1.1-B.1.6

Sullivan, W.G., and Claycombe, W.W. (1977). *Fundamentals of Forecasting*, Reston Publishing Co. Inc., Reston, Virginia, 40p.

Teshmont Consultants Ltd. (1974). "Feasibility study of delivering power from Gull Island Hydro-electric site to Newfoundland," St. John's, Newfoundland, Table 15-3.

Tham T.B., (1980). "Fast Relief for the pain of Contract Cash Flows," *1980 Transactions of the American Association of Cost Engineers*, 24th Annual Meeting, Washington, D.C., pp. A.2.1-A.2.5

TSC, (1987). *Precision Estimating Plus*, Timberline Software Corporation, Beaverton, Oregon 97005, USA.

Warszawski, A., (1982a) "Risk Element in Profit Planning Under Inflation," *Journal of the Construction Division*, ASCE, Vol. 108, No. CO4, Proc. Paper 17593, pp. 624-638.

Warszawski, A., (1982b) "Managerial Decisions under Inflation," *Journal of the Construction Division*, ASCE, Vol. 108, No. CO1, Proc. Paper 16908, pp. 147-157.

Willenbrock, J.H., (1973). "Utility Function Determination for Bidding Models," *Journal of the Construction Division*, ASCE, Vol. 99, No. CO1, pp. 133-153.

Wonnacott T.H. and Wonnacott R.J., (1984). *Introductory Statistics for Business and Economics*, John Wiley & Sons, Toronto, pp. 601-612.

Appendix A

MODELLING COST EFFECTS OF ALLOCATION OF ESCALATION RISK

The cost effects of the allocation of escalation risk can be modelled by applying the principles of the cardinal utility theory. Such modelling assumes that a party attempts to maximize its expected utility value and is indifferent to assignments with equal expected utility values. This example quantifies, using the expected utility theory, the cost effects of complete allocation of escalation risk of a given construction project to the contractor as compared to the complete allocation of the risk to the owner.

A.1 Assumptions

It is assumed that the owner is risk neutral and thus values any risk at its expected monetary value. It is assumed that the contractor is risk averse and that the contractors utility function has been determined in the manner described in Chapter 2. The above mentioned utility function of the contractor is listed in Table A.1 and depicted in Figure A.1. The contractors utility function shows that the contractors marginal utility for each additional $

1,000,000 profit decreases sharply after the first $ 4,000,000 profit. It is further assumed that both the owner and the cor ' ractors perception of possible escalation rates and their respective probabilities of occurrence is the same.

Table A.1: Contractors utility function over relevant range of profits

Profit in Dollars	Utility in Utiles
0	0
1,000,000	15
2,000,000	30
3,000,000	46
4,000,000	60
5,000,000	62
6,000,000	64
7,000,000	66
8,000,000	68
9,000,000	70
10,000,000	72

A.2 Project description and escalation scenarios

A construction project with an unescalated cost of $40,000,000 to the contractor is used. To this is added the contractors required markup of $4,000,000 and the cost of escalation. The cost of escalation to be included in the contractors bid or the owners budget depends on who bears the escalation risk.

The project is to be built over a period of three years starting three months from the date of tender. Three possible escalation scenarios are

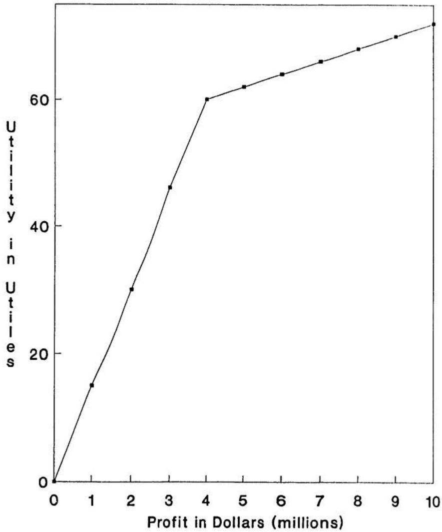


Figure A.1: Contractors utility function over relevant range of profits predicted namely:

1. A mean escalation rate of 3% with a 25% chance of occurrence. This would cause a possible $2,000,000 increase in construction costs.
2. A mean escalation rate of 7% with a 50% chance of occurrence. This would cause a possible $6,000,000 increase in construction costs.
3. A mean escalation rate of 10% with a 25% chance of occurrence. This would cause a possible $8,000,000 increase in construction costs.

The project cost characteristics under the various escalation scenarios are summarized below:

Unescalated construction costs	$ 40,000,000
Contractors markup	$ 4,000,000
Probability of 3% escalation rate	0.25
Increased costs due to 3% escalation rate	$ 2,000,000
Probability of 7% escalation rate	0.50
Increased costs due to 7% escalation rate	$ 6,000,000
Probability of 10% escalation rate	0.25
Increased costs due to 10% escalation rate	$ 8,000,000

A.3 Evaluation of costs when escalation risk is assigned to owner

The contractors utility function depicted in Figure 1 indicates that a profit of $4,000,000 has a utility of 60 utiles. When the owner assumes the risk of escalation, the contractors profit of $4,000,000 is certain and thus has a probability of occurrence of unity (1). The expected utility value to the contractor is thus:

$$\begin{aligned} EUV = & \ \Sigma U(x_i) * P(x_i) \\ = & \ U(4,000,000) * P(4,000,000) \\ = & \ 60 * 1 \ = \ 60 \end{aligned}$$

The owner is risk neutral and thus the costs are valued by the owner at their expected monetary value. The owner therefore assesses the costs of escalation as:

$$\begin{aligned} EMV = & \ \Sigma x_i * P(x_i) \\ = & \ 2,000,000 * 0.25 + 6,000,000 * 0.5 + 8,000,000 * 0.25 \\ = & \ 5,500,000 \end{aligned}$$

The total budgeted costs to the owner when he bears the escalation risk would therefore be:

Unescalated construction costs	\$ 40,000,000
Contractors markup	\$ 4,000,000
Expected escalation costs	\$ 5,500,000
Total costs to owner	\$49,500,000

A.4 Evaluation of costs when escalation risk is assigned to contractor

The contractor, in an attempt to maximize his expected utility value, will charge a premium for the risk of escalation such that the expected utility value of the contract with escalation risk is the same as the expected utility value of the contract without escalation risk (Erickson and O'Connor, 1979). From an iterative search using the contractors utility function, the contractor would have to charge \$7,000,000 for escalation costs and the risks involved in order for the utility value of the contract to the contractor when the contractor bears escalation risk to equal 60 utiles, which is the utility value of the contract to the contractor when the client bears the escalation risk.

The expected utility value of the contract to the contractor is determined as follows:

$$
\begin{aligned}
EUV = & \ \Sigma U(x_i) * P(x_i) \\
= & \ U(51,000,000 - 42,000,000) * P(51,000,00 - 42.000.000) + \\
& \ U(51,000,000 - 46,000,000) * P(51,000,00 - 46,000,000) + \\
& \ U(51,000,000 - 48,000,000) * P(51,000,00 - 48,000,000) \\
= & \ U(9,000,000) * P(9,000,000) + \\
& \ U(5,000,000) * P(5,000,000) + \\
& \ U(3,000,000) * P(3,000,000) \\
= & \ 70 * 0.25 + 62 * 0.5 + 46 * 0.25 \ = \ 60
\end{aligned}
$$

With the contractor bearing the escalation risk, the total contract sum and the total costs to the owner would therefore be as follows:

Unescalated construction costs	\$ 40,000,000
Contractors markup	\$ 4,000,000
Escalation costs and risk as charged by contractor	\$ 7,000,000
Total contract sum and costs to owner	\$51,000,000

A.5 Interpretation

Use of the cardinal utility value theory predicts that the risk averse contractor would appraise the costs due to escalation at \$7,000,000 whereas the risk neutral owner appraises the escalation costs at \$5,500,000. Therefore the owner would pay a premium of \$1,500,000 for the contractor to assume the risk of escalation. From purely expected utility value considerations, the owner would save \$ 1,500,000 if he bore the risk of cost escalation.

Appendix B

LISTING AND PLOTS OF INDICES

This appendix contains the data used in illustrating the various methods of forecasting cost indices discussed in Chapter 3. The data consists of lists of the monthly values from January 1983 to September 1989 of various indices extracted from Statistics Canada's Construction Price Statistics, Catalogue 62-007, Third quarter 1989, pp. 11, 16, 22, and 24, and Third quarter 1986, pp. 11, 16, 22, and 24, reproduced with the permission of the Minister of Supply and Services Canada, 1990. This appendix also includes the plots of the monthly values of these indices with time. In the tables and plots that follow, the following abbreviations are used for the various indices:

PWBII	=	Prefabricated Wooden Building Industry Index
UWRI	=	Union Wage Rate Index
CBMPI	=	Construction Building Materials Price Index
CBLR	=	Commercial Bank Lending Rate Index
S&PMPI	=	Sawmill and Planing Mill Products Index
AMI	=	Architectural Materials Index

Table B.1: Monthly values of selected indices

Month-year	PWBII	UWRI	CBMPI	CBLR	S&PMPI	AMI
1-1983	105.2	116.2	107.3	62.2	106.7	104.6
2-1983	105.9	116.2	107.7	59.6	106.3	105.1
3-1983	105.9	116.2	108.9	59.6	108.2	106.2
4-1983	107.6	116.2	109.5	57	110	106.6
5-1983	107.7	126.1	110.8	57	119.6	107
6-1983	107.3	126.1	112.8	57	128.4	108.6
7-1983	109.7	126.2	114.4	57	126.1	111.4
8-1983	110	126.2	113.5	57	112.4	111
9-1983	110.2	126.3	112	57	104.7	109.9
10-1983	110.4	126.4	112	57	105.3	109.8
11-1983	110.5	127.4	112.2	57	102.7	110.7
12-1983	110.9	127.2	112.7	57	106.9	110.5
1-1984	111.6	127.2	113.5	57	108.2	111.1
2-1984	111.5	127.2	114.3	57	113.8	111.6
3-1984	111.7	127.2	114.9	59.6	116.2	112.3
4-1984	110.7	127.2	115.6	59.6	114.1	113.4
5-1984	110.8	127.9	114.7	62.2	107.5	113.2
6-1984	110.8	127.9	114.4	64.8	102.8	113.6
7-1984	111.2	127.9	114.7	70	102	113.9
8-1984	111.4	127.7	114.9	67.4	104.2	113.9
9-1984	111.4	127.7	114.8	67.4	101.4	114.5
10-1984	112	127.7	115.8	64.8	100.9	116
11-1984	111.8	127.8	115.6	62.2	101.3	116.1
12-1984	111.9	127.8	115.8	58.3	103	115.8
1-1985	112.8	127.8	116.2	57	105.5	115.7
2-1985	112.9	127.8	117.4	59.6	105.5	117
3-1985	112.9	127.8	117.8	60.9	106.3	117.6

Table B.2: Monthly values of selected indices (cont'd)

Month-year	PWBII	UWRI	CBMPI	CBLR	S&PMPI	AMI
4-1985	113.8	127.8	118.2	55.7	105.4	118.3
5-1985	113.8	132.1	118.8	54.4	110.2	118.6
6-1985	114	132.1	120	54.4	112.6	119.4
7-1985	114.2	132.1	120.4	54.4	111.7	120.5
8-1985	114.3	132.1	121.2	53.1	109.4	120.4
9-1985	114.3	132.1	121.3	53.1	108.6	122
10-1985	115.1	132.2	121.6	51.8	106.7	122.9
11-1985	115.3	132.2	121.7	51.8	104.3	123.5
12-1985	115.3	132.2	121.9	51.8	106.8	123.1
1-1986	116.3	132.2	124.2	57	108.5	124.4
2-1986	116.5	132.2	125.1	67.4	108.5	125.6
3-1986	117.2	132.2	126.5	62.2	117.4	126.1
4-1986	118.1	132	129.6	58.3	122.9	129.2
5-1986	119.1	132.8	129.8	53.1	120.2	129.3
6-1986	120	134.5	129.6	53.1	114.8	129.4
7-1986	119.4	135.2	139.5	50.5	114.8	129.2
8-1986	119.5	135.3	130.3	50.5	120.7	130.1
9-1986	119.6	136.6	131.3	50.5	124.8	130.7
10-1986	119.6	136.8	131.6	50.5	122.4	131.4
11-1986	119.8	136.8	131.6	50.5	119.4	131.9
12-1986	119.8	136.8	133	50.5	116.5	132.6
1-1987	120.6	136.9	132.4	48	114.8	134
2-1987	120.7	136.9	131.8	48	118	133
3-1987	123.3	136.9	132.3	45.4	117.1	132.6
4-1987	125	136.9	133.2	48	117.3	133.5
5-1987	125.2	140.7	133.4	49.2	116.9	133.1
6-1987	125.2	140.7	133.6	49.2	118.9	132.9

Table B.3: Monthly values of selected indices (cont'd)

Month-year	PWBII	UWRI	CBMPI	CBLR	S&PMPI	AMI
7-1987	125.7	140.7	134.4	49.2	120.6	134
8-1987	125.7	140.7	136.1	51.8	123	135.2
9-1987	126.1	140.7	136.2	51.8	122.6	135.7
10-1987	126.5	140.7	137.7	50.5	120.3	137.5
11-1987	126.3	141	137.1	50.5	121.1	136.2
12-1987	126.4	141	137.4	50.5	120.9	136.7
1-1988	130.6	141.1	140.1	50.5	122.8	139.1
2-1988	130.6	141.1	139.8	50.5	122.6	139.1
3-1988	130.6	141.1	140.2	50.5	122.1	139
4-1988	130.7	141.1	140.6	53.1	122.5	139.7
5-1988	130.8	146.6	140.4	53.1	121	139.6
6-1988	131	148	141.1	55.7	125.5	140
7-1988	131.6	149.1	142	55.7	126.1	140.9
8-1988	131.6	149.2	140.6	58.3	122.6	139.1
9-1988	131.8	149.2	140.1	60.9	121.2	138.9
10-1988	132.1	149.2	140.3	60.9	119.8	139.4
11-1988	132.1	149.3	140.6	60.9	119.9	139.4
12-1988	132.4	149.3	140.7	63.5	119.2	139.4
1-1989	135.4	149.3	141.1	63.5	122	139.3
2-1989	135.9	149.3	141.4	66.1	122.6	139.8
3-1989	135.9	149.3	142	70	123.4	140.1
4-1989	135.6	149.3	142.2	70	123.7	140.7
5-1989	135.5	157.1	142.8	70	124.3	141.9
6-1989	135.6	157.1	144	70	126.6	143.1
7-1989	135.6	157.2	144.7	70	128.7	144.1
8-1989	135.6	157.2	144.1	70	128.2	143.1
9-1989	135.6	157.2	143.9	70	127.8	143.1

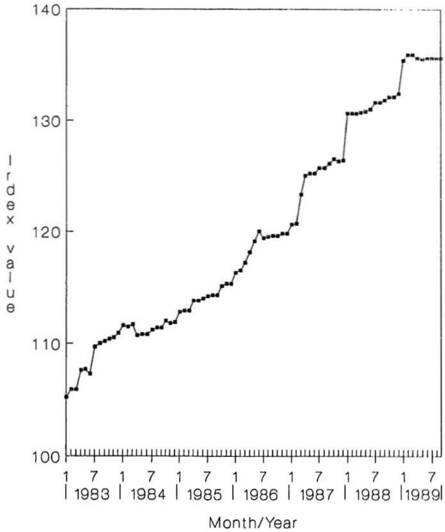


Figure B.1: Plot of the PWBII

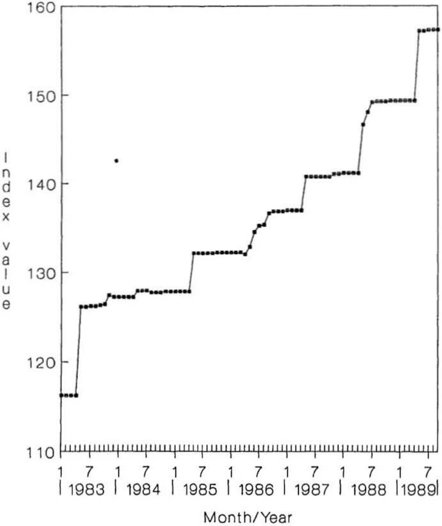


Figure B.2: Plot of the UWRI

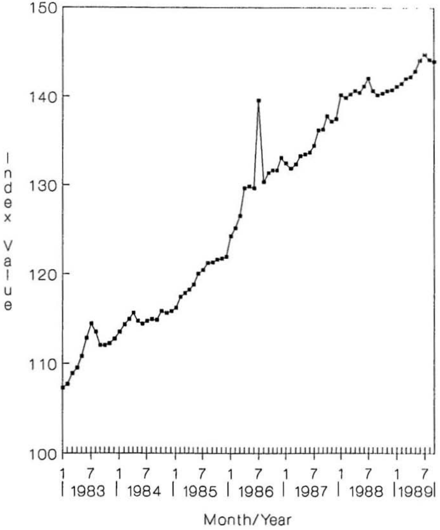


Figure B.3: Plot of the CBMPI

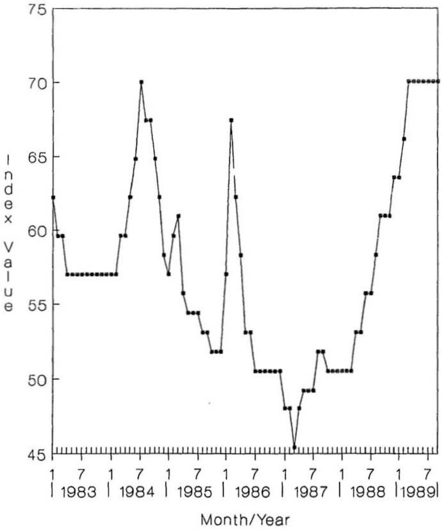


Figure B.4: Plot of the CBLR

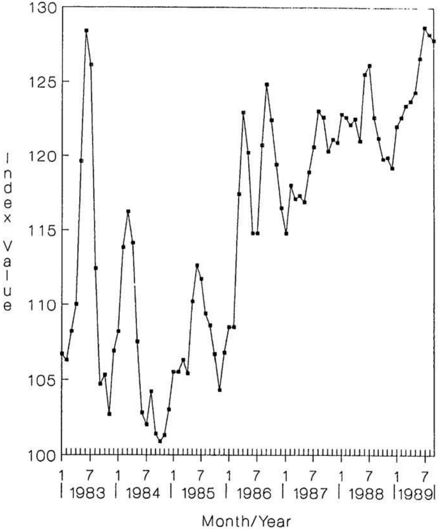


Figure B.5: Plot of the S&PMPI

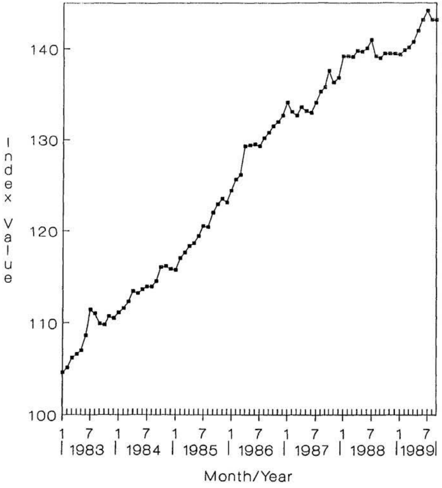


Figure B.6: Plot of the AMI

Appendix C

RAW HOSPITAL COST DATA

This appendix contains the data extracted from the clients copies of the payment certificates used to demonstrate the application of polynomial regression models in Chapter 4. The data given is in its original form without any adjustments.

Table C.1: Data for Hospital 1

Original contract sum $ 13 million
Project substantially complete at Certificate No. 28

Payment Certificate Number	Months from start of construction	Cumulative value of work complete
1	1	155350
2	2	245000
3	3	335480
4	4	1266580
5	5	1738720
6	6	2345870
7	7	3204921.
8	8	4340273.
9	9	5234001.
10	10	5885148.
11	11	6608810.
12	12	7735620.
13	13	8129956.
14	14	8617431.
15	15	8961876.
16	16	9468183.
17	17	9947017.
18	17	9947017.
19	18	10756753
20	19	11814260
21	20	12005940
22	21	12368831
23	22	12634591
24	23	12928998
25	24	13007383
26	25	13159989
27	26	13267651
28	27	13318849
29	28	13318849
30	35	13318849
31	37	13366349

Table C.2: Data for Hospital 2

Original contract sum $ 11.5 million
Project substantially complete at Certificate No. 28

Payment Certificate Number	Months from start of construction	Cumulative value of work complete
1	1	259181
2	2	536245
3	3	1169099
4	4	2069483
5	5	3118400
6	6	3862482
7	7	4418447
8	7	5015363
9	8	5672905
10	9	5888905
11	10	6477067
12	11	7185887
13	11	7185887
14	12	8013210
15	13	8907365
16	14	9504248
17	14	9504248
18	15	9850414
19	16	10370475
20	17	10675430
21	18	10812876
22	19	10991294
23	20	11214905
24	21	11371251
25	22	11500362
26	23	11580990
27	24	11646605
28	24	11759010
29	28	11805187
30	30	11836419
31	30	11840149
32	31	11904449

Table C.3: Data for Hospital 3

Original contract sum $ 3.15 million
Project substantially complete at Certificate No. 13

Payment Certificate Number	Months from start of construction	Cumulative value of work complete
1	1	365420
2	2	690150
3	3	845880
4	4	1233835
5	5	1413143
6	6	1675685
7	7	2081034
8	8	2298072
9	9	2708912
10	10	2926057
11	11	3064554
12	12	3104526
13	14	3173972
14	15	3256173
15	19	3314965
16	31	3353463
17	55	3353463

Table C.4: Data for Hospital 4

Original contract sum $ 6 million
Project substantially complete at Certificate No. 24

Payment Certificate Number	Months from start of construction	Cumulative value of work complete
1	1	292921
2	2	899936
3	3	1043364
4	4	1157104
5	5	1512904
6	6	1701747
7	7	1897501
8	8	2328792
9	9	2601125
10	10	2769282
11	11	3125603
12	12	3422026
13	13	3773018
14	14	4104366
15	15	4308812
16	16	4687583
17	17	5040172
18	18	5285645
19	19	5384220
20	20	5598562
21	21	5749942
22	22	5860455
23	23	5998638
24	26	6016123
25	30	6028000
26	36	6036879

Appendix D

REGRESSION ANALYSIS AND MODEL ACCURACY COMPUTATION SPREADSHEETS

This appendix consists of two sections, namely Section D.1 and D.2. Section D.1 contains reproductions of the contents of LOTUS 123 spreadsheets used to obtain the polynomial regression parameters for the four hospital projects discussed in Chapter 4. The value of the work complete at various months is obtained by adjusting the data extracted from the clients copies of the payment certificates and given in Appendix C. The necessary adjustments are discussed in Chapter 4.

Section D.2 consists of copies of computer printouts of the LOTUS 123 spreadsheets used to compute the amount of escalation estimated for each hospital using various other hospital regression model equations. All data used in these spreadsheets is extracted from the data given in section D.1 of this appendix. Discussion of the necessary adjustments made and the results of these computations is given in Chapter 4.

D.1 REGRESSION ANALYSIS SPREAD-SHEETS

Regression analysis on actual cash flow for Hospital 1

Month	Percent Time P	P^2	P^3	Value of work completed	Percent complete
0	0	0	0	0	0.00
1	3.85	14.79	56.90	155350	1.17
2	7.69	59.17	455.17	580480	4.36
3	11.54	133.14	1536.19	1266580	9.51
4	15.38	236.69	3641.33	1738720	13.05
5	19.23	369.82	7111.97	2345870	17.61
6	23.08	532.54	12289.49	3204922	24.06
7	26.92	724.85	19515.25	4340273	32.59
8	30.77	946.75	29130.63	5234001	39.30
9	34.62	1198.22	41477.01	5885148	44.19
10	38.46	1479.29	56895.77	6608811	49.62
11	42.31	1789.94	75728.27	7735621	58.08
12	46.15	2130.18	98315.89	8129956	61.04
13	50.00	2500.00	125000.00	8617432	64.70
14	53.85	2899.41	156121.98	8961876	67.29
15	57.69	3328.40	192023.21	9468184	71.09
16	61.54	3786.98	233045.06	9947017	74.68
17	65.38	4275.15	279528.90	10756753	80.76
18	69.23	4792.90	331816.11	11814260	88.70
19	73.08	5340.24	390248.07	12005940	90.14
20	76.92	5917.16	455166.14	12368832	92.87
21	80.77	6523.67	526911.70	12634592	94.86
22	84.62	7159.76	605826.13	12928998	97.07
23	88.46	7825.44	692250.80	13007383	97.66
24	92.31	8520.71	786527.08	13159990	98.81
25	96.15	9245.56	888996.36	13267652	99.62
26	100.00	10000.00	1000000.00	13318849	100.00

Regression Output:

Constant		-3.28027	
Std Err of Y Est		2.120815	
R Squared		0.996746	
No. of Observations		27	
Degrees of Freedom		23	
Std Err of Y Est		3.104295	
X Coefficient(s)	1.08293572	0.011149	-0.00011
Std Err of Coef.	0.12619556	0.002964	0.000019
Degrees of Freedom		23	

Regression analysis on actual cash flow for Hospital 2

Month	Percent Time P	P^2	P^3	Value of work completed	Percent complete
	0	0	0	0	0
1	4.17	17.36	72.34	259181	2.23
2	8.33	69.44	578.70	536245	4.60
3	12.50	156.25	1953.13	1169099	10.04
4	16.67	277.78	4629.63	2069483	17.77
5	20.83	434.03	9042.25	3118400	26.78
6	25.00	625.00	15625.00	3862482	33.16
7	29.17	850.69	24811.92	5015363	43.06
8	33.33	1111.11	37037.04	5672905	48.71
9	37.50	1406.25	52734.38	5888905	50.56
10	41.67	1736.11	72337.96	6477067	55.61
11	45.83	2100.69	96281.83	7185887	61.70
12	50.00	2500.00	125000.00	8013210	68.80
13	54.17	2934.03	158926.50	8907365	76.48
14	58.33	3402.78	198495.37	9504248	81.61
15	62.50	3906.25	244140.63	9850414	84.58
16	66.67	4444.44	296296.30	10370475	89.04
17	70.83	5017.36	355396.41	10675430	91.66
18	75.00	5625.00	421875.00	10812876	92.84
19	79.17	6267.36	496166.09	10991294	94.37
20	83.33	6944.44	578703.70	11214905	96.29
21	87.50	7656.25	669921.88	11371251	97.64
22	91.67	8402.78	770254.63	11500362	98.74
23	95.83	9184.03	880136.00	11580990	99.44
24	100.00	10000.00	1000000.00	11646605	100.00

Regression Output:			
Constant		-4.02075	
Std Err of Y Est		2.317829	
R Squared		0.996178	
No. of Observations		25	
Degrees of Freedom		21	
X Coefficient(s)	1.35345535	0.007714	-0.00011
Std Err of Coef.	0.14211349	0.003342	0.000021

Regression analysis on actual cash flow for Hospital 3

Month	Percent Time P	P^2	P^3	Value of work completed	Percent complete
1	7.14	51.02	364.43	365420	11.51
2	14.29	204.08	2915.45	690150	21.74
3	21.43	459.18	9839.65	845880	26.65
4	28.57	816.33	23323.62	1233835	38.87
5	35.71	1275.51	45553.94	1413143	44.52
6	42.86	1836.73	78717.20	1675685	52.79
7	50.00	2500.00	125000.00	2081034	65.57
8	57.14	3265.31	186588.92	2298072	72.40
9	64.29	4132.65	265670.55	2708912	85.35
10	71.43	5102.04	364431.49	2926057	92.19
11	78.57	6173.47	485058.31	3064554	96.55
12	85.71	7346.94	629737.61	3104526	97.81
14	100.00	10000.00	1000000.00	3173972	100.00

	Regression Output:		
	Constant	2.837277	
	Std Err of Y Est	2.577911	
	R Squared	0.995687	
	No. of Observations	14	
	Degrees of Freedom	10	
X Coefficient(s)	0.90217330	0.013598	-0.00012
Std Err of Coef.	0.18975080	0.004503	0.000029

Regression analysis on actual cash flow for Hospital 4

Month	Percent Time P	P^2	P^3	Value of work completed	Percent complete
	0.00	0.00	0.00	0	0.00
1	3.85	14.79	56.90	292921	4.87
2	7.69	59.17	455.17	899936	14.96
3	11.54	133.14	1536.19	1043364	17.34
4	15.38	236.69	3641.33	1157104	19.23
5	19.23	369.82	7111.97	1512904	25.15
6	23.08	532.54	12289.49	1701747	28.29
7	26.92	724.85	19515.25	1897501	31.54
8	30.77	946.75	29130.63	2328792	38.71
9	34.62	1198.22	41477.01	2601126	43.24
10	38.46	1479.29	56895.77	2769282	46.03
11	42.31	1789.94	75728.27	3125604	51.95
12	46.15	2130.18	98315.89	3422026	56.88
13	50.00	2500.00	125000.00	3773019	62.72
14	53.85	2899.41	156121.98	4104367	68.22
15	57.69	3328.40	192023.21	4308812	71.62
16	61.54	3786.98	233045.06	4687584	77.92
17	65.38	4275.15	279528.90	5040172	83.78
18	69.23	4792.90	331816.11	5285645	87.86
19	73.08	5340.24	390248.07	5384221	89.50
20	76.92	5917.16	455166.14	5598563	93.06
21	80.77	6523.67	526911.70	5749943	95.58
22	84.62	7159.76	605826.13	5860456	97.41
23	88.46	7825.44	692250.80	5998639	99.71
26	100.00	10000.00	1000000.00	6016123	100.00

Regression Output:			
Constant		3.562784	
Std Err of Y Est		1.874430	
R Squared		0.997107	
No. of Observations		25	
Degrees of Freedom		21	
X Coefficient(s)	0.80118475	0.014197	-0.00012
Std Err of Coef.	0.11255961	0.002677	0.000017

D.2 REGRESSION MODEL ACCURACY COMPUTATION SPREADSHEETS

Application of other regression equations to Hospital 1 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 2 model results: Percent complete	Hospital 2 model results: Value completed in interval	Hospital 2 model results: Escalation amount	Hospital 4 model results: Percent complete	Hospital 4 model results: Value completed in interval	Hospital 4 model results: Escalation amount
0	0.00	0	0.00				0			0		
1	3.85	155350	1.17	155350	1.00398	618	1.29	172173	685	6.85	912001	3629
2	7.69	580480	4.36	425130	1.01199	5095	6.80	733086	8786	10.51	487967	5848
3	11.54	1266580	9.51	686100	1.02005	13760	12.45	753480	15111	14.51	532998	10689
4	15.38	1738720	13.05	472140	1.02819	13309	18.23	768873	21674	18.81	572572	16140
5	19.23	2345870	17.61	607150	1.03639	22093	24.08	779264	28356	23.37	606691	22076
6	23.08	3204922	24.06	859052	1.04465	38358	29.97	784654	35036	28.14	635354	28370
7	26.92	4340273	32.59	1135352	1.05298	60153	35.86	785043	41593	33.08	658561	34892
8	30.77	5234001	39.30	893728	1.06138	54856	41.72	780430	47902	38.16	676312	41511
9	34.62	5885148	44.19	651147	1.06984	45478	47.51	770816	53836	43.33	688606	48094
10	38.46	6608811	49.62	723662	1.07837	56716	53.19	756200	59266	48.55	695445	54504
11	42.31	7735621	58.08	1126810	1.08697	98002	58.72	736583	64063	53.78	696827	60605
12	46.15	8129956	61.04	394335	1.09564	37714	64.06	711965	68093	58.98	692754	66255
13	50.00	8617432	64.70	487475	1.10438	50881	69.19	682345	71221	64.11	683224	71313
14	53.85	8961876	67.29	344445	1.11318	38985	74.05	647724	73312	69.13	668238	75634
15	57.69	9468184	71.09	506307	1.12206	61800	78.62	608102	74225	74.00	647797	79070
16	61.54	9947017	74.68	478834	1.13101	62731	82.85	563478	73820	78.66	621899	81474
17	65.38	10756753	80.76	809736	1.14003	113384	86.70	513852	71953	83.10	590545	82692
18	69.23	11814260	88.70	1057507	1.14912	157693	90.15	459226	68478	87.26	553735	82571
19	73.08	12005940	90.14	191680	1.15828	30339	93.15	399598	63248	91.10	511469	80956
20	76.92	12368832	92.87	362892	1.16752	60790	95.67	334968	56113	94.58	463747	77685
21	80.77	12634592	94.86	265760	1.17683	46993	97.66	265337	46919	97.66	410569	72600
22	84.62	12928998	97.07	294407	1.18621	54822	99.09	190705	35511	100.00	311539	58012
23	88.46	13007383	97.66	78385	1.19567	15338	99.93	111071	21733	100.00	0	0
24	92.31	13159990	98.81	152607	1.20520	31316	100.00	9876	2027	100.00	0	0
25	96.15	13267652	99.62	107662	1.21481	23127	100.00	0	0	100.00	0	0
26	100.00	13318849	100.00	51197	1.22450	11494	100.00	0	0	100.00	0	0
			Estimated escalation			1205846			1102960			1154620

Application of other regression equations to Hospital 1 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 3 model results: Percent complete	Value completed in interval	Escalation amount
0	0.00	0	0.00				0		
1	3.85	155350	1.17	155350	1.00398	618	6.50	865925	3446
2	7.69	580480	4.36	425130	1.01199	5095	10.53	536159	6426
3	11.54	1266580	9.51	686100	1.02005	13760	14.87	578830	11608
4	15.38	1738720	13.05	472140	1.02819	13309	19.50	616044	17366
5	19.23	2345870	17.61	607150	1.03639	22093	24.36	647802	23572
6	23.08	3204922	24.06	859052	1.04465	38358	29.42	674105	30100
7	26.92	4340273	32.59	1135352	1.05298	60153	34.64	694952	36820
8	30.77	5234001	39.30	893728	1.06138	54856	39.97	710342	43600
9	34.62	5885148	44.19	651147	1.06984	45478	45.38	720276	50306
10	38.46	6608811	49.62	723662	1.07837	56716	50.82	724754	56802
11	42.31	7735621	58.08	1126810	1.08697	98002	56.26	723777	62949
12	46.15	8129956	61.04	394335	1.09564	37714	61.64	717343	68607
13	50.00	8617432	64.70	487475	1.10438	50881	66.94	705453	73633
14	53.85	8961876	67.29	344445	1.11318	38985	72.11	688107	77882
15	57.69	9468184	71.09	506307	1.12206	61800	77.10	665305	81207
16	61.54	9947017	74.68	478834	1.13101	62731	81.89	637046	83458
17	65.38	10756753	80.76	809736	1.14003	113384	86.42	603332	84482
18	69.23	11814260	88.70	1057507	1.14912	157693	90.65	564162	84126
19	73.08	12005940	90.14	191680	1.15828	30339	94.55	519536	82232
20	76.92	12368832	92.87	362892	1.16752	60790	98.08	469453	78641
21	80.77	12634592	94.86	265760	1.17683	46993	100.00	256148	45294
22	84.62	12928998	97.07	294407	1.18621	54822	100.00	0	0
23	88.46	13007383	97.66	78385	1.19567	15338	100.00	0	0
24	92.31	13159990	98.81	152607	1.20520	31316	100.00	0	0
25	96.15	13267652	99.62	107662	1.21481	23127	100.00	0	0
26	100.00	13318849	100.00	51197	1.22450	11494	100.00	0	0
				Estimated escalation		1205846			1102557

Application of other regression equations to Hospital 2 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 1 model results: Percent complete	Value completed in interval	Escalation amount	Hospital 4 model results: Percent complete	Value completed in interval	Escalation amount
1	4.17	259181	2.23	259181	1.00398	1031	1.42	165098	657	7.14	831433	3308
2	8.33	536245	4.60	277064	1.01199	3321	6.45	586664	7031	11.16	467836	5607
3	12.50	1169099	10.04	632854	1.02005	12692	11.78	620629	12447	15.56	513116	10290
4	16.67	2069483	17.77	900384	1.02819	25381	17.36	649033	18295	20.30	552330	15570
5	20.83	3118400	26.78	1048917	1.03639	38168	23.13	671878	24448	25.33	585479	21304
6	25.00	3862482	33.16	744082	1.04465	33225	29.04	689162	30772	30.59	612561	27352
7	29.17	5015363	43.06	1152881	1.05298	61082	35.06	700885	37134	36.03	633578	33568
8	33.33	5672905	48.71	657542	1.06138	40359	41.13	707048	43398	41.60	648528	39806
9	37.50	5888905	50.56	216000	1.06984	15086	47.21	707651	49424	47.24	657413	45915
10	41.67	6477067	55.61	588162	1.07837	46096	53.24	702693	55072	52.91	660231	51745
11	45.83	7185887	61.70	708820	1.08697	61648	59.18	692174	60200	58.55	656984	57140
12	50.00	8013210	68.80	827323	1.09564	79125	64.99	676096	64662	64.11	647671	61943
13	54.17	8907365	76.48	894155	1.10438	93329	70.61	654456	68310	69.54	632292	65997
14	58.33	9504248	81.61	596883	1.11318	67557	75.99	627257	70995	74.79	610847	69138
15	62.50	9850414	84.58	346165	1.12206	42253	81.10	594497	72564	79.80	583336	71202
16	66.67	10370475	89.04	520061	1.13101	68132	85.87	556176	72863	84.52	549759	72023
17	70.83	10675430	91.66	304955	1.14003	42702	90.27	512295	71735	88.90	510116	71430
18	75.00	10812876	92.84	137446	1.14912	20496	94.25	462854	69019	92.88	464407	69251
19	79.17	10991294	94.37	178419	1.15828	28240	97.75	407852	64555	96.43	412632	65312
20	83.33	11214905	96.29	223611	1.16752	37459	100.00	262209	43924	99.47	354791	59433
21	87.50	11371251	97.64	156346	1.17683	27646	100.00	0	0	100.00	61267	10834
22	91.67	11500362	98.74	129111	1.18621	24042	100.00	0	0	100.00	0	0
23	95.83	11580990	99.44	80628	1.19567	15776	100.00	0	0	100.00	0	0
24	100.00	11646605	100.00	65615	1.20520	13465	100.00	0	0	100.00	0	0
			Estimated escalation			898311			937508			928167

Application of other regression equations to Hospital 2 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 3 model results: Percent complete	Hospital 3 model results: Value completed in interval	Hospital 3 model results: Escalation amount
1	4.17	259181	2.23	259181	1.00398	1031	6.82	794733	3162
2	8.33	536245	4.60	277064	1.01199	3321	11.23	513210	6151
3	12.50	1169099	10.04	632854	1.02005	12692	16.00	556068	11152
4	16.67	2069483	17.77	900384	1.02819	25381	21.10	592860	16712
5	20.83	3118400	26.78	1048917	1.03639	38168	26.45	623586	22691
6	25.00	3862482	33.16	744082	1.04465	33225	32.02	648246	28945
7	29.17	5015363	43.06	1152881	1.05298	61082	37.74	666840	35331
8	33.33	5672905	48.71	657542	1.06138	40359	43.57	679368	41699
9	37.50	5888905	50.56	216000	1.06984	15086	49.46	685830	47900
10	41.67	6477067	55.61	588162	1.07837	46096	55.35	686227	53782
11	45.83	7185887	61.70	708820	1.08[illegible]37	61648	61.20	680557	59190
12	50.00	8013210	68.80	827323	1.09564	79125	66.94	668822	63966
13	54.17	8907365	76.48	894155	1.10438	93329	72.53	651020	67952
14	58.33	9504248	81.61	596883	1.11318	67557	77.92	627153	70983
15	62.50	9850414	84.58	346165	1.12206	42253	83.04	597219	72897
16	66.67	10370475	89.04	520061	1.13101	68132	87.86	561220	73524
17	70.83	10675430	91.66	304955	1.14003	42702	92.32	519155	72695
18	75.00	10812876	92.84	137446	1.14912	20496	96.36	471023	70238
19	79.17	10991294	94.37	178419	1.15828	28240	99.94	416826	65975
20	83.33	11214905	96.29	223611	1.16752	37459	100.00	6644	1113
21	87.50	11371251	97.64	156346	1.17683	27646	100.00	0	0
22	91.67	11500362	98.74	129111	1.18621	24042	100.00	0	0
23	95.83	11580990	99.44	80628	1.19567	15776	100.00	0	0
24	100.00	11646605	100.00	65615	1.20520	13465	100.00	0	0
			Estimated escalation			898311			886058

Application of other regression equations to Hospital 3 data

							Hospital 1 model results			Hospital 2 model results		
Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Percent complete	Value completed in interval	Escalation amount	Percent complete	Value completed in interval	Escalation amount
1	7.14	365420	11.51	365420	1.00398	1454	4.98	158182	629	6.00	190447	758
2	14.29	690150	21.74	324730	1.01199	3892	14.14	290771	3485	16.57	335414	4020
3	21.43	845880	26.65	155730	1.02005	3123	23.96	311612	6249	27.44	345129	6921
4	28.57	1233835	38.87	387955	1.02819	10936	34.20	324818	9156	38.38	347210	9787
5	35.71	1413143	44.52	179308	1.03639	6525	44.61	330390	12022	49.15	341657	12432
6	42.86	1675685	52.79	262543	1.04465	11723	54.95	328328	14661	59.49	328470	14667
7	50.00	2081034	65.57	405349	1.05298	21476	64.99	318631	16882	69.19	307649	16300
8	57.14	2298072	72.40	217038	1.06138	13322	74.48	301301	18494	77.98	279193	17137
9	64.29	2708912	85.35	410840	1.06984	28694	83.19	276336	19300	85.64	243103	16979
10	71.43	2926057	92.19	217144	1.07837	17018	90.87	243737	19103	91.92	199379	15626
11	78.57	3064554	96.55	138497	1.08697	12045	97.28	203504	17699	96.59	148021	12874
12	85.71	3104526	97.81	39973	1.09564	3823	100.00	86361	8260	99.39	89029	8515
14	100.00	3173972	100.00	69446	1.10877	7554	100.00	0	0	100.00	19271	2096
			Estimated escalation			141585			145939			138112

Application of other regression equations to Hospital 3 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 4 model results: Percent complete	Value completed in interval	Escalation amount
1	7.14	365420	11.51	365420	1.00398	1454	9.97	316322	1259
2	14.29	690150	21.74	324730	1.01199	3892	17.56	240893	2887
3	21.43	845880	26.65	155730	1.02005	3123	26.07	270217	5419
4	28.57	1233835	38.87	387955	1.02819	10936	35.24	291213	8209
5	35.71	1413143	44.52	179308	1.03639	6525	44.82	303880	11058
6	42.86	1675685	52.79	262543	1.04465	11723	54.53	308220	13763
7	50.00	2081034	65.57	405349	1.05298	21476	64.11	304231	16119
8	57.14	2298072	72.40	217038	1.06138	13322	73.31	291914	17917
9	64.29	2708912	85.35	410840	1.06984	28694	81.86	271269	18946
10	71.43	2926057	92.19	217144	1.07837	17018	89.49	242296	18990
11	78.57	3064554	96.55	138497	1.08697	12045	95.95	204994	17829
12	85.71	3104526	97.81	39973	1.09564	3823	100.00	128524	12292
14	100.00	3173972	100.00	69446	1.10877	7554	100.00	0	0
			Estimated escalation			141585			144687

Application of other regression equations to Hospital 4 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete"	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 1 model results: Percent complete	Value completed in interval	Escalation amount	Hospital 2 model results: Percent complete	Value completed in interval	Escalation amount
	0	0	0									
1	3.85	292921	4.87	292921	1.00398	1166	1.04	62780	250	1.29	77770	309
2	7.69	899936	14.96	607015	1.01199	7275	5.66	277710	3328	6.80	331135	3969
3	11.54	1043364	17.34	143428	1.02005	2876	10.53	293036	5877	12.45	340347	6826
4	15.38	1157104	19.23	113740	1.02819	3206	15.62	306103	8629	18.23	347300	9790
5	19.23	1512904	25.15	355800	1.03639	12947	20.89	316911	11532	24.08	351994	12808
6	23.08	1701747	28.29	188843	1.04465	8432	26.30	325460	14532	29.97	354428	15826
7	26.92	1897501	31.54	195754	1.05298	10371	31.81	331749	17577	35.86	354604	18788
8	30.77	2328792	38.71	431291	1.06138	26472	37.39	335780	20610	41.72	352520	21637
9	34.62	2601126	43.24	272334	1.06984	19020	43.00	337551	23575	47.51	348177	24318
10	38.46	2769282	46.03	168157	1.07837	13179	48.61	337062	26417	53.19	341576	26770
11	42.31	3125604	51.95	356321	1.08697	30990	54.16	334316	29076	58.72	332715	28937
12	46.15	3422026	56.88	296422	1.09564	28350	59.64	329310	31495	64.06	321594	30757
13	50.00	3773019	62.72	350993	1.10438	36636	64.99	322045	33614	69.19	308215	32171
14	53.85	4104367	68.22	331348	1.11318	37503	70.18	312521	35372	74.05	292577	33115
15	57.69	4308812	71.62	204446	1.12206	24955	75.18	300737	36708	78.62	274679	33527
16	61.54	4687584	77.92	378771	1.13101	49622	79.95	286695	37559	82.85	254523	33344
17	65.38	5040172	83.78	352588	1.14003	49372	84.44	270393	37862	86.70	232107	32501
18	69.23	5285645	87.86	245473	1.14912	36604	88.63	251832	37552	90.15	207432	30932
19	73.08	5384221	89.50	98575	1.15828	15603	92.47	231012	36565	93.15	180498	28569
20	76.92	5598563	93.06	214342	1.16752	35906	95.92	207933	34832	95.67	151305	25346
21	80.77	5749943	95.58	151380	1.17683	26768	98.96	182595	32288	97.66	119853	21193
22	84.62	5860456	97.41	110513	1.18621	20579	100.00	62589	11655	99.09	86141	16040
23	88.46	5998639	99.71	138183	1.19567	27038	100.00	0	0	99.93	50171	9817
26	100.00	6016123	100.00	17484	1.21481	3756	100.00	0	0	100.00	4461	958
			Estimated escalation			528626			526906			498250

Application of other regression equations to Hospital 4 data

Month	Percent Time	Cumulative Actual Value of work completed	Actual Percent complete	Value completed in interval	Escalation factor at 10%	Actual escalation amount	Hospital 3 model results: Percent complete	Hospital 3 model results: Value completed in interval	Hospital 3 model results: Escalation amount
	0	0	0						
1	3.85	292921	4.87	292921	1.00398	1166	6.00	391138	1556
2	7.69	899936	14.96	607015	1.01199	7275	10.53	242183	2903
3	11.54	1043364	17.34	143428	1.02005	2876	14.87	261457	5243
4	15.38	1157104	19.23	113740	1.02819	3206	19.50	278267	7844
5	19.23	1512904	25.15	355800	1.03639	12947	24.36	292612	10647
6	23.08	1701747	28.29	188843	1.04465	8432	29.42	304493	13596
7	26.92	1897501	31.54	195754	1.05298	10371	34.64	313910	16632
8	30.77	2328792	38.71	431291	1.06138	26472	39.97	320861	19694
9	34.62	2601126	43.24	272334	1.06984	19020	45.38	325349	22723
10	38.46	2769282	46.03	168157	1.07837	13179	50.82	327371	25657
11	42.31	3125604	51.95	356321	1.08697	30990	56.26	326930	28434
12	46.15	3422026	56.88	296422	1.09564	28350	61.64	324024	30990
13	50.00	3773019	62.72	350993	1.10438	36636	66.94	318653	33260
14	53.85	4104367	68.22	331348	1.11318	37503	72.11	310818	35179
15	57.69	4398812	71.62	204446	1.12206	24955	77.10	300518	36681
16	61.54	4687584	77.92	378771	1.13101	49622	81.89	287754	37698
17	65.38	5040172	83.78	352588	1.14003	49372	86.42	272525	38161
18	69.23	5285645	87.86	245473	1.14912	36604	90.65	254832	38000
19	73.08	5384221	89.50	98575	1.15828	15603	94.55	234674	37144
20	76.92	5598563	93.06	214342	1.16752	35906	98.08	212052	35522
21	80.77	5749943	95.58	151380	1.17683	26768	100.00	115702	20459
22	84.62	5860456	97.41	110513	1.18621	20579	100.00	0	0
23	88.46	5998639	99.71	138183	1.19567	27038	100.00	0	0
26	100.00	6016123	100.00	17484	1.21481	3756	100.00	0	0
			Estimated escalation			528626			498025