DETERMINATION OF A PRICE INDEX FOR ESCALATION OF BUILDING CONSTRUCTION COSTS IN TURKEY

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ABSTRACT

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Construction cost indices are developed to measure the degree of price variations in construction material and labor costs. However, each specific type of construction is a combination of unique set of materials and labor. As such, the degree of price variations referring to each specific type of construction shall be measured by specific price indices, in order to achieve more accurate results. In Turkey, Producer Price Index (PPI) published by State Statistics Institute is commonly used for the escalation of building costs. This study aims to compare the existing cost indices as well as new alternative cost indices in terms of their adequacy for the representation of variations in the building costs in Turkey. The developed price indices will be tested to measure their fit with the cost of building projects, will be compared with the price indices published by the Ministry of Public Works and Settlement and also State Statistics Institute, and finally the most adequate price indices among the examined ones to be used for building projects will be selected. Moreover, models representing past price movements will be developed.

Key Words: Price Index, Escalation, Correlation, Regression Analysis.

ÖZ

TÜRKİYE'DE YER ALAN BİNA PROJELERİNİN MALİYETLERİNİN ESKALASYONU İÇİN BİR FİYAT ENDEKSİ BELİRLENMESİ

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İnşaat fiyat endeksleri, inşaat malzeme ve işçilik maliyetlerindeki fiyat değişikliklerinin seviyesini ölçmek amacıyla geliştirilmiştir. Bununla birlikte her tip inşaat, kendine özgü malzeme ve işçilik grubu kombinasyonundan oluşmuştur. Dolayısıyla, daha hassas sonuçlar elde edebilmek için, her tip inşaat projesine tekabül eden fiyat değişikliklerinin seviyesi, kendilerine özgü fiyat endeksleriyle ölçülmelidir. Türkiye'de bina maliyetlerinin eskalasyonu için genellikle Devlet İstatistik Enstitüsü tarafından yayınlanan Üretici Fiyat Endeksi kullanılmaktadır. Bu çalışma, Türkiye'de bina maliyetlerindeki değişikliklerin temsil edilebilmesi için mevcut fiyat endeksleri ile yeni alternatif fiyat endekslerinin uygunlukları açısından kıyaslanmasını amaçlamaktadır. Geliştirilen fiyat endeksleri, bina projelerinin sözleşme fiyatlarına uygunluklarını ölçmek için test edilecek, Bayındırlık ve İskan Bakanlığı ve ayrıca Devlet İstatistik Enstitüsü tarafından yayınlanan fiyat endeksleriyle kıyaslanacak ve sonuçta incelenen endeksler arasından bina projeleri için kullanilabilecek en uygun fiyat endeksleri seçilecektir. Bunlara ilaveten, geçmişteki fiyat hareketlerini temsil eden modeller geliştirilecek ve geliştirilen modellerin sonuçları gelecekteki fiyat hareketlerinin tahmin edilmesi açısından ayrıca ele alınacaktır.

Anahtar Sözcükler: Fiyat Endeksi, Eskalasyon, Korelasyon, Regresyon Analizi.

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TO MY FAMILY,

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LIST OF ABBREVIATIONS

BCEPC	Belgian Chemical Engineering Plant Cost
BCI	Building Cost Index
CEPC	Chemical Engineering Plant Cost
CI	Cost Index
CPI	Consumer Price Index
ENR	Engineering News Record
EUROSTAT	Statistical Office of the European Community
MAPE	Mean Absolute Percent Error
MPWS	Ministry of Public Works and Settlement
M&S	Marshall and Swift
NFCC	Nelson-Farrar Construction Cost
OECD	Organization for Economic Co-operation and Development
$PBPI_1$	Produced Building Price Index 1
$PBPI_2$	Produced Building Price Index 2
$PBPI_3$	Produced Building Price Index 3
$PBPI_4$	Produced Building Price Index 4
PPI	Producer Price Index
SSI	State Statistics Institute
TL	Turkish Lira
UC	Unit Cost
UK	United Kingdom

US	United States
USD	United States Dollar
VAT	Value Added Tax

CHAPTER I

INTRODUCTION

Construction cost indices are developed to measure the degree of price variations in construction material and labor costs. However, each specific type of construction is a combination of unique set of materials and labor. This leads to the fact that cost variations for different types of constructions shall be measured by different types of cost indices, which actually are developed by measuring the price variations regarding those specific sets of material and labor involved in those kinds of construction projects.

The objective of this study was to examine which cost index, among Consumer Price Index (CPI), Producer Price Index (PPI), Building Cost Index (BCI) published by the State Statistic Institute, Cost Index (CI) published by Ministry of Public Works and Settlement and the Cost Indices produced in this study using the data compiled from the database of several Turkish contractors, would provide the most precise result to be used for the escalation purposes of building projects in Turkey. In addition, it was aimed to develop models to predict the future values of the most precise two cost indices selected to assist for cost estimating of the building projects.

Determination of the current value of a past project plays an important role in the procurement process, since the applicants of any tender process could be compared in terms of the amounts of the projects completed by them in the past. In this aspect, the past projects of the contractors could be compared quantitatively, either in the prequalification or post qualification process. The base of comparison usually and mainly depends on the projects completed by these contractors, examining the contract prices of those completed projects, besides other criteria regarding the technical and administrative issues. However, since the periods of the execution of the projects for each contractor may vary in time, the impact of inflation should be included in these comparisons.

Escalation is not only used to determine current value of the past projects; but also to predict the future costs of the construction projects. As most of the construction projects usually take several months to complete, costs are expected to increase during the construction of the project, even with the decreasing inflation rates achieved in Turkey over the last decades.

In most of the contracts which the payments are going to be made in TL, a method for the escalation of construction prices is included. In the majority of these contracts, especially for the public projects, price escalation is calculated by a formula which is a linear function of the producer price index published by the State Statistics Institute.

In some projects where payments are made in TL, there may be no price escalation included in the contract. For these projects, the contractor should estimate future construction costs for the contract period and include these costs in the bid amount. Payments could be made in foreign currencies for some projects that are contracted in Turkey. Even the payments are going to be made in foreign currencies, the contractors bidding for these projects should also consider possible increases in the construction costs in Turkey, as most of the time local labor and material are used by the contractors.

The Producer Price Index (PPI) published by the State Statistics Institute and the Cost Index (CI) published by the Ministry of Public Works and Settlement are commonly used for the escalation purposes of building project costs in Turkey.

As such, cost indices have been developed to measure the impact of inflation over several sectors. In this study, it was aimed to compare the adequacy of several available cost indices including the ones developed and to select the index which gives with the best performance to escalate the costs for building projects. The comparison of these indices will be performed by conducting statistical techniques, such as regression analysis and validation.

The Statistics Directorate of OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996), on the other hand, notes that construction price indices are primarily used for analysis of price movements and for price formation in the construction industry, for price escalation clauses in construction contracts, and for deflation of components of the national accounts. The same organization specifies the primary uses of such indices as:

- Measuring the changes of prices of construction materials for construction work.

  In developing a program of projects, preparing estimates, comparing estimates with bids, and scheduling projects within funding limits it is necessary to have some way of judging price movements. The aim is to express physical volumes of work needed for future construction work in value terms.

- Studying the impacts of changing prices over the total construction cost and selling prices of the construction work.

- Measuring the expenditure of consumed materials at constant prices.

- Estimating the short-term evolution of prices.

- To determine replacement values for insurance purposes.

  The use of construction price indices (where quality and other changes in the price determining characteristics of the construction operations observed have been eliminated) can have considerable impact if they are used to determine replacement values. If construction work of the original quality is no longer supplied because of substantial changes in materials, techniques, etc. the replacement values obtained from the use of construction price indices may be considerably less than the amount actually required to be spent on the replacement.

- Realizing price-index readjustments of construction contracts.

- Planning the production of materials and checking the efficiency of entrepreneurial units.

- Deflating components of the national accounts.

  In addition to the compilation of national accounts at current prices there is a necessity in having constant price measures that separate the effects of price and volume increases (or decreases). This necessity is particularly strong in countries experiencing high inflation.

In many countries, cost indices are published by the governmental organizations to escalate the costs of the past projects of the contractors and to classify them into groups with respect to their experience. In Turkey, Ministry of Public Works and Settlement publishes every year an index to be used for the mentioned purposes. However, this index is a general index calculated with the contribution of many parameters and may not be suitable, perhaps not sufficient, for building projects, in which many of these parameters may not exist or may not cover the significant amount of the same. Similarly, PPIs published by the State Statistics Institute is another index that is also commonly used for escalation purposes of the building projects. However, this index is designed to reflect price movements in general products which are not generally directly related with the building costs. Hence, this study aimed to address specifically the building projects, by developing new cost indices to be used for the purpose of escalating the costs of building projects for civil works and by comparing them with the existing published indices with the use of statistical techniques. In addition, future values of these indices were also aimed to be predicted by constructing models, which enabled to also predict the future cost of such kind of projects. Again, statistical techniques were conducted to quantify the accuracy of the predicted values and the indices providing the most accurate estimations were selected finally.

This study is structured as an introductory chapter, three main chapters and a summary chapter.

- Chapter One – *Introduction* – This chapter involves the purpose of the study and presents general information about the concept.

- Chapter Two – *Literature Review* – This chapter presents the background information about the studies related to the subject.

- Chapter Three – *General Information about Price Indices* – In this chapter, general information about price indices and the relevant calculation methods are presented.

- Chapter Four – *Methodology and Data Analysis* – The methodology used to develop the produced indices, by the analysis of the collected data, is explained in detail in this chapter. The accuracy of the models developed to predict the future cost of the selected indices is also discussed.

- Chapter Five – *Conclusions and Recommendations* – This chapter gives a brief review of the studies conducted and states whether the target of the study has been achieved.

CHAPTER II

LITERATURE REVIEW

Many studies have been conducted to develop special price indices for different types of construction projects; each calculated by using different weights assigned to the rates of price changes of material and labor costs included therein. The developed price indices were also tested to define how much they could describe the price variations in the costs of the subject types of projects. On the other hand, some of the studies were performed to select the most applicable index among the available ones. This chapter aims to present information about previous studies regarding price indices developed for different types of projects, with detailed explanations about the calculation techniques.

Pintelon and Geeroms (1996) touched on the subject of deficiency of plant cost indices to be applicable for countries other than US. Their study referred to the utilization of these cost indices and development of them for a non-US country. In the research, the authors illustrated development of a cost index for chemical process plants in Europe, more specifically in Belgium. Pintelon and Geeroms (1996) conducted this study with the involvement of the data regarding the cost escalation period from 1965 to 1994. As cost indices have no dimension, a base year was assigned according to the available data. Then they obtained cost indices by dividing the actual price in a given year by the price in the base year, and multiplying the result by 100. The actual price in a given year was calculated by taking the average of the unit prices throughout the given year into consideration.

The number of the construction of chemical plants was not sufficient to develop valid statistics on the cost of these plants. Moreover, as chemical plants include large variety of equipments; trustworthy statistics was difficult to be obtained. Most of the indices for complex costs had been built up from commodity and less complex components. An example of a fairly simple cost index was the two parameter model by Cran (1976):

$$(Index)_{Cran} = 0.7 * I_{Labor} + 0.3 * I_{Steel} \quad [2.1]$$

Where I_{Labor} is the labor price index and I_{Steel} is the steel price index.

Data for this index was composed of only two general and well-known indices. This resulted in making the model easy to use as these indices were readily available for many countries. On the other hand, according to Pintelon and Geeroms (1996), the disadvantage of this model was that since the model was based on only two parameters, this made it an oversimplification of the price escalation. Using this model over a long period of time might have caused unreliable results.

On the other hand, there were several cost indices for chemical plants but most of them were related to US situation. The authors focused on four US plant cost indices: the Nelson-Farrar construction cost (NFCC) index, the Engineering News-Record (ENR) index, the Chemical Engineering Plant Cost (CEPC) index and the Marshall and Swift (M&S) index. The ENR index was not directly related with chemical engineering applications and NFCC index was specifically focused on petroleum industry. Due to the fact that the remaining two indices (M&S and CEPC) were most appropriate for chemical process industries, the CEPC index was found to be more suitable rather than the M&S index. The same index was also considered to be the most complete and most reliable index. As a result, the new Belgian chemical engineering plant cost index (BCEPC) developed in this study was based on and compared with the CEPC index.

While forming this BCEPC index, Pintelon and Geeroms (1996) followed four main steps:

1. Building a cost index model

2. Comparing the resulting cost index with the CEPC

3. Fine-tuning the new cost index for the Belgian situation on hand

4. Final evaluation step

In the first step, a cost index model was developed using those US statistical data that are also readily available for the European countries. In step 2, the cost index model was compared with the CEPC index. If the index would be closer to the CEPC index, the evaluation of the index would have been more suitable. In order to obtain a satisfactory result, the authors stated that Step 1 and Step 2 might be repeated alternately. Two parameters were taken into consideration in order to test the "quality of fit" of the model developed with the CEPC index. The authors emphasized on the fact that the small changes in the weights of the model should not affect the value of the index largely. This control was also mentioned as the stability control of the new index.

While developing the BCEPC index, the authors tried two-parameter, three-parameter, four-parameter and five-parameter models. In two-parameter model, t*he cost of the chemical installation could be divided in two major parts: labor and material.* The carbon steel price was taken as material parameter since it was the most used material in chemical plants. Productivity improvement was considered as the third parameter, inflation index as the forth parameter and crude oil price as the fifth one. Having developed four different cost index models, Pintelon and Geeroms (1996) compared all these four models individually with two other chemical process indices of US origin (ENR and CEPC). It was understood that there were not a significant difference between four-parameter and five-parameter model. Moreover, the authors stated that four-parameter model was more suitable than the other due to the simplicity and the significantly inferior of the "quality of fit" of the four-parameter model. Finally, the formula of the model was expressed as:

$$Index = 0.27 * I_{Steel} + 0.38 * I_{Product-adj-lab} + 0.35 * I_{Inflation} \qquad [2.2]$$

Where I_{Steel} is the steel price index, $I_{prod\_adj\_lab}$ is the productivity adjusted labor cost index and $I_{Inflation}$ is the inflation index.

In step 3, a weighted index was formed according to a weighted average of the Belgian indices. Past projects and trade relations indicated the way to obtain this individual weighted index.

Finally, in step 4, the authors continued with the further evaluation of the new index, with the purpose of checking whether it would fail to estimate escalation correctly or not. Hence, the escalation of the cost of a project over a certain time period was compared with the predicted escalation of the cost index. In case of the failure where the new cost index would estimate the escalation correctly, it was stated that either it would be required to make a new CEPC model and to evaluate it similarly, or a careful and critical examination of the underlying assumptions would be needed.

As a result of these studies, the impact of a (changed) cost index on some current management ratios was examined by the authors. As regards to the findings of the study, the resulting cost index, which was based on the readily available data of well-known chemical engineering plants in Belgium, was meant for use in chemical engineering plant cost applications, specifically geared at the Belgian situations. The authors concluded with the fact that the produced index seemed to lead to satisfactory results. However, they also recommended that such cost index should be treated with some specific cautions, since it was unlikely to be really up-to-date; it was based on model but not on actual Belgian data; and it was an average value.

Remer, Huynh, Agarwal, Auchard and Nelson (1998) stated that the inflation and location indices were used in order to adjust costs for time and location. Hence they focused on the use of these indices, different types of indices available, and some caveats. As Remer et al. (1998) stated, a cost estimator would adjust the variables like time and location when the cost of similar projects was available. At this point, the usage of cost index came into scene in order to make this calculation. On the other hand, selecting the most suitable index to use was actually the main problem in using inflation indices. The authors illustrated *a large number of indices to help the cost estimators locate the correct one to use.*

There were four types of cost indices: compiler intent, measured cost, industry and location. Compilers use cost indices for the following: general purpose, contractor price, valuation and special purpose. General purpose cost indices cover a broad spectrum of a particular industry or a type of cost, such as the engineering news record (ENR) index (Remer et al., 1998). On the other hand, the authors mentioned that contractor price indices measure the change in selling prices of various types of buildings, such as the Turner general building index. They also defined valuation indices and special purpose indices as representing replacement costs, such as the Marshall and Swift industrial equipment index and being used for a particular industry, such as the Nelson-Farrar Refinery Cost Index or the Handy Whitman Public Utilities Index respectively.

Remer, Huynh, Agarwal, Auchard and Nelson (1998) used the data of 70 indices by dividing these data in two groups which are US Indexes and International Indexes. The US Indices contains indexes applicable to projects located within the US, on the other hand, International Indexes contains indexes compiled with data from areas outside the US. They also categorized these 70 indices according to their industry category, type of cost category, and descriptions to find potentially useful indices. In order to find the most appropriate cost index to be used, they suggested contacting index compilers for detailed information on how the indexes are constructed. Finally, Remer, Huynh, Agarwal, Auchard and Nelson (1998) gave a list of caveats in using inflation and location indexes as follows:

• Inflation indexes are statistically weighted composite averages, and thus, should only be used for ballpark or order-of-magnitude calculations.

• Inflation indexes are usually limited in scope to a particular industry or industrial segment. As noted by Miller, the engineering news record construction index may be misapplied in the process industries (Park, 1973). The ENR Index was intended for use with civil engineering projects involving large quantities of unskilled labor, which may not be the case for process plants or process plant equipment.

• Inflation indexes measuring similar types of cost may be constructed of different weighted averages of sub-costs. For example, the Bureau of Labor Statistics compiles two Employment Cost Indexes for various types of workers, one for benefits and the other for wages and salaries (Monthly Labor Review, 1995). Examining the cost measured by a particular inflation index and how the index is calculated increases the probability of accurate cost estimate calculation.

- Some indexes do not account for radical technological changes in design and construction. As technology progresses, the cost weightings for a particular index can change, which may or may not be reflected by the inflation index. For example, production technology developments may shift manufacturing costs from labor to plant equipment. An inflation index tracking the manufacturing cost may not adjust to these changes. Cost estimators should always check the applicability of cost indexes used in their calculations.

- Inflation indexes compare costs for products that evolve over time. Comparing the cost of a chemical plant constructed today versus 20 years ago should reflect not only the increased cost of materials, but also the additional cost of government-mandated environmental equipment. Cost estimators should be aware that some inflation indexes do not adjust for these additional costs.

- Inflation index calculations become increasingly inaccurate as the time interval between data points is increased, i.e., a 5 year calculation is probably more accurate than a 20 year escalation.

- Some inflation indexes are based on published list prices (rather than market prices) and time averaged labor conditions. These indexes can be insensitive to short-term economic cycle swings.

The study by Remer and Mattos (2003) updated and expanded upon the study by Remer, Huynh, Agarwal, Auchard and Nelson (1998) on cost and location factors used in the US and internationally. In their study, 43 US cost and location factors and 30 international cost and location factors for 12 countries were used. In addition, cost scale-up factors for a wide variety of equipment, plants and processes from air pollution abatement to waste-to-energy facilities were presented. Remer and Mattos (2003) reviewed the use of these indices and scale-up factors, and presented caveats for their use.

Wilmot and Cheng (2003) made a study in order to develop a model that estimates future highway construction costs in Lousiana. They stated that when projects are costed, their costs are estimated in terms of the current cost of the project, and this estimate is not adjusted for the year in which the project is scheduled for implementation. These cost increases can be significant and are, of course, cumulative across projects; also, they rise at an increasing rate each year into the future. Estimating future highway construction was the focus of their study. In order to describe the change in overall construction costs in the future, a predictive construction cost index was adopted in their study.

Wilmot and Cheng (2003) used the data of 2.827 highway and bridge contracts, which were obtained of highway construction projects let by the Lousiana DOTD during the period 1984-1997. Five submodels of price estimation were formed in order to predict overall highway construction costs. In their study, the most influential factors were found to be the cost of the material, labor, and equipment used in constructing the facility. On the other hand, characteristics of individual contracts and the contracting environment in which contracts were let also affect construction costs. In particular, contract size, duration, location, and the quarter in which the contract is let were found to have a significant impact on contract cost. Bid volume, bid volume variance, number of plan changes, and changes in construction practice, standards, or specifications also make a significant impact on contract costs.

The model developed by Wilmot and Cheng (2003) reproduced past overall construction costs reasonably accurately at the aggregate level. Predicted overall construction costs were not significantly different from observed costs at the 99% level of significance. The model estimated that highway construction costs in Louisiana were going to increase more rapidly to the year 2015 than would be anticipated if past trends were extrapolated or if the rate of general inflation were used as an estimate of future increase in costs. The authors stated that their model would be used by highway officials in Louisiana to test alternative contract management strategies. Increasing contract sizes, reducing the duration of contracts, reducing bid volume and bid volume variance, reducing the number of plan changes, and reducing the proportion of contracts let in the fourth quarter all serve to reduce overall construction costs. They also mentioned that highway officials would assess the impact of strategies they believe were achievable by applying the model. Finally, it can be said that, the model would assist in estimating future construction costs and providing the means to produce more reliable construction programs.

Wang and Mei (1998) made a model for forecasting construction cost indices in Taiwan. The major determining factors to make up the construction cost indices were mentioned as:

1. The number of difference

2. The required periods of preceding construction cost indices

3. The weight associated with each preceding construction cost index

4. The mean value of the series of construction cost indices that have been converted into a stationary series

5. The estimation of the errors between the predicted values of construction cost indices and the observed values of construction cost indices

Focusing on the above mentioned factors Wang and Mei (1998) set up an analytical model in order to predict the current and future construction cost indices. Then, they tested the feasibility of the model by using the observed data of the construction cost indices obtained from the Executive Yuan of the Republic of China. After setting up and testing the model, the results showed that the model is adequate in forecasting the trend values of construction cost indices and can also provide the predicted values of them in Taiwan.

CHAPTER III

GENERAL INFORMATION ABOUT PRICE INDICES

3.1 Introduction

This study aims to compare the existing cost indices as well as new alternative cost indices in terms of their adequacy for the representation of variations in the building costs in Turkey, which will be explained in the following section. A study conducted by the Statistics Directorate of the OECD (1994 (a) , 1996, 1994 (b)) and EUROSTAT (1995, 1996) dictates that the demand for adequate construction price indices arises from the need to assess real changes in the output from these activities which cannot be derived solely through reference to regular building and construction statistics. These indices have a wide range of applications including deflation of components of national accounts, adjustment of construction contracts and leases, and as a basis for indexation for insurance purposes (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996). However, before going into the details of the methodology used to derive such cost indices and compare them in terms of adequacy; it shall be better to present information about the available cost indices of Turkey, which are calculated by the governmental organizations and updated periodically.

A variety of tools are used to measure price changes taking place in an economy. These include consumer price indices (CPIs), producer price indices (PPIs), price indices relating to specific goods and/or services, and GDP deflators (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) &

EUROSTAT, 1995, 1996). This chapter provides information about the concept of price index, available price indices and the methods regarding how they are calculated. These indices consist of CPI, PPI and BCI; each calculated and published periodically by the State Statistics Institute and CI, which is published by the Ministry of Public Works and Settlement. A detailed investigation through the calculation methods of these indices will create a suitable media for the reader to have a better understanding regarding the concept of price index.

3.2 General

The first cost indices were developed by Carli in 1750 to determine the effects of the discovery of America on the purchasing power of money in Europe (Ostwald, 1992). One type of cost index is the inflation index, which attempts to adjust costs of similar projects during different time periods. The engineering news record (ENR) index started in 1909 is the oldest inflation index currently used by engineers (Grogan, 1994).

In index calculation, various methods are used according to the type and coverage of the index. Therefore, it can be an easy way to examine the index calculation methods with the index types. SSI Turkey (2002) gives a classification of the indices as follows:

1. Location and Time Indices

2. Constant and Variable Indices

3. Simple and Compound Indices

Location index is defined as the measurement of rational alteration which is indicated by any statistical variable such as population, production and price among the locations like regions, provinces, etc (SSI Turkey, 2002). Similarly, time index is the measurement of rational alteration which is indicated by any statistical variable such as population, production and price with respect to time. These indices are based on a time series and used on implementation widely. The classification of the indices as constant and variable indices is usually valid for the time series. Constant-based index is the description for the index obtained by explaining the complete set of the indices as the percentage of the average of some certain periods or a certain period. The constant period, where the data of various periods are compared, does not change (SSI Turkey, 2002).

When the base period is variable, in other words when all the values of a current period are compared with those of the previous period, it is called variable-based index.

Finally, simple indices are calculated to cover only one material. On the other hand, compound indices cover two or more materials.

3.3 Price Index

SSI Turkey (2002) defines the price index as a tool which measures the rate at which the prices of goods and services are changing over time. A basket of goods and services according to the market under interest (consumer, producer, export, import, etc.) and representing this market is established and the prices of the selected materials are monitored periodically. The price indices are named according to the good and service market where the prices are monitored. The consumer price index, producer price index, export price index, import price index can be examples for these indices.

The price indices are required for determining the structure of a country, taking an economic decision, establishing the purchasing power of the members, determining the costs and wages, establishing the retail prices for goods and services purchased by consumer and determining the change of these prices in time. On the other hand, they are required for confirming the socio-economic condition and tendency, determining the conjuncture and taking future decisions.

The basic variables required for the calculation of price indices are:

- Basket of goods and services
- Base year weights
- Base year prices
- Current prices

3.3.1 Basket of goods and services

Basket of goods and services or basket of goods is a specific good and service list in which prices are focused periodically in order to calculate indices. In indices, it is very hard to focus all of the price movements of the goods and services. Therefore, they are limited with important goods and services according to a criterion and named as basket of good and service. The goods and services chosen are defined as type, quantity and quality, and updated according to the purpose of the index.

3.3.2 Weight

The weight is defined as the share which the selected goods and services gain with respect to their values in the total basket and which is required for the calculation of the index. There are two types of weights:

Constant weight: The weights of the materials of which consumption or production structure are not affected by the months or seasons are called constant weight.

Variable Weight: The weights of the materials of which consumption or production structure are affected by the seasons are called in this way.

3.3.3 Base year price

Base year price is the average price of the goods and services used to calculate the price indices in 12 months of the base year.

3.3.4 Current Price

Current price is the existing price of the goods and services used to calculate the price indices.

The indices are renewed periodically because SSI Turkey (2002) states that in Turkey, which is socially, economically, and culturally in continuous and in rapid change, the products and services also change in light of new technological advances. This, in return, results in alterations in consumer behavior. There are changes in the structures and shares of the sectors, firms, and resources in production. Certain goods and services leave their positions to new ones, and others loose their significance in production. Reflecting these changes to indices in the structure of consumption and production and updating the indices are mandatory. On the international platform, it is advised that the indexes are renewed every five years (SSI Turkey, 2002).

3.4 Construction Price Indices

3.4.1 General

Construction Price Indices are calculated by the statistical directorates of countries to meet the demand arising from the need to assess real changes in the output from these activities (i.e. to create a constant value series) which cannot be derived solely through reference to regular building and construction statistics (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996). The Statistics Directorate of the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995,1996) also notes that construction price indices are used in guaranteed value clauses in rental, leasing, and other contracts; adjustment of sales contracts for buildings under construction; and as a basis for indexation for insurance purposes. They are also used to deflate national accounts estimates of output of construction activities, and gross fixed capital formation in residential construction. In summary, construction price indices are used to track changes/trends in the cost (or price) of construction. They do not provide information on the current market value of construction work, earning capacity, or rental values.

The compilers of construction price indexes face some difficult problems specific to construction. They are stated briefly in (Turvey Demon, http://www.turvey.demon.co.uk/ Construction%20Price%20Indexes.doc, last access June 9, 2005) and as follows:

1. Construction projects are heterogeneous; each is unique, except for standard pre-fabricated single-family houses,

2. The specifications in construction contracts are complex and lengthy,

3. Since work under many contracts takes months or years to complete, it is necessary to distinguish between contract (tender) prices agreed at a point in time and the prices of current construction output over a number of time periods. When contracts include an escalation adjustment for wages or the prices of materials, output prices are not known in advance,

4. Where there is single main contractor, the contract price includes a major non-quantified item (known as “Preliminaries” in the UK) onto which most of the contractor’s profits and overheads are loaded (TurveyDemon, http://www.turvey.demon.co.uk/Construction%20Price%20Indexes.doc, last access June 9, 2005).

Construction price indexes may be used for two distinct purposes

1. The deflation of current expenditure on construction projects to provide estimates of construction expenditure at constant prices.

2. As a measure of one component of inflation.

These purposes impose different requirements in two respects:

1. For deflation, division of construction expenditure by the index must be done period by period over the duration of each contract to yield a measure of construction output period by period. For analyzing inflation, on the other hand, what counts is the time when a contract is signed, not the time(s) of payment or delivery. Hence the whole of the agreed

contract price should enter an inflation price index in the period when it is agreed,

2. For deflation, a current-based index is needed in order to divide into value to derive a fixed-base estimate of expenditure at current prices. But for measuring inflation, a fixed-base index is required, both to conform with the fixed-base indexes used for other types of expenditure, and to provide a meaningful period to period indicator of changes in agreed prices(TurveyDemon,http://www.turvey.demon.co.uk/Construction%20Price%20Indexes.doc, last access June 9, 2005).

In broad terms, construction price indices provide measures of changes in the prices of either the inputs to, or outputs of, construction activity. However, terminology used in the context of price indices for construction activity varies between countries. There is also considerable variation in the inclusion/exclusion of items such as transport costs, consumption taxes, fittings, etc (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996). The terms used in this study to represent the construction price indices have been defined by the SSI Turkey (2002); since the scope of the study is drawn with the data of the actual projects located in Turkey.

Most of the information used in the compilation of construction price indices are derived from the supply side of the industry (i.e. from construction firms, sub-contractors, materials supply firms, etc.). However, a unique feature of construction activity that impacts on the compilation of construction price indices is that in most situations the completed building or construction is not produced and sold by one construction contractor alone. Normally, the client (or architect charged by the client with the responsibility of supervising the construction) concludes contracts with a number of firms. Most of these are predominantly part of the construction branch; however they may also belong to other branches of the economy (e.g. steel construction, manufacture of fixtures, engineering, etc.). The client (or supervising architect) invites construction contractors (who in turn may invite sub-contractors) to undertake work at a building or construction site. The work to be done is referred to as "work category". If the offer is accepted the work is performed and supplied to the client/architect as a "product". The work categories correspond to the "goods" or "products" observed in other price statistics. From the perspective of the production performed by a construction contractor, the prices in question may be either the prices of the various inputs to the construction process paid by the construction contractor, or the prices received by the construction contractor from the client for the output of the construction contractor. The latter are producer prices and come close to the concept of a PPI (i.e. in the context of the construction industry the prices received by the producers of work categories). The construction contractor's sales prices of individual work categories from the construction sector are in most cases also the purchase prices of the client.

In summary, construction price indices may be described as indices compiled from:

- prices paid by the contractor for inputs to the construction process; or
- the price received for the completed output of construction activity paid by the client; or
- the selling price including all of the demand side cost elements paid by the purchaser or final owner,

(Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996).

3.4.2 Outline of Processes in Developing a Construction Price Index

As with both CPIs and PPIs, the development and compilation of price indices for construction activity is a complex procedure consisting of a long and varied set of operations, as stated by the Statistics Directorate of OECD (1994 (a), 1996, 1994 (b)) & EUROSTAT (1995, 1996). The usefulness of the construction indices compiled also depends on having a clear understanding of the purposes of the indices, and the characteristics of the construction industry in the country where it is located. The study conducted by the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996) lists these characteristics which include:

- the range of construction activities conducted throughout the country;
- construction techniques commonly used for each type of construction activity, together with an idea of the rate of change in techniques used;
- types of entities/organizations undertaking construction activity, and their characteristics (e.g. size, industry concentration, etc.);
- administrative arrangements for the maintenance of building/construction standards;
- administrative arrangements for government authorization of individual construction projects.

The Statistics Directorate of OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996) lists the major processes in the development and compilation of construction price indices using the “model price” methodology outlined above as the following:

- Selection of a small, representative group of recently constructed buildings, civil engineering projects, etc. as models. The number of models required depends on the range of construction activity to be included in the index, diversity of the specifications for each type of activity, and regional diversity.

- Specification of the hundreds of detailed tasks or component trades in the construction of these model projects. These are prepared using architectural drawings and specifications. Also involves the development of components for the general requirements (overheads and profit margins) of the main construction contractor.

- Selection of a sample of components. The selection of components within each trade area is based on both money value and the coverage of significant materials and/or products involved. A goal might be to select components which cover at least 70 per cent of the total value of the trade.

- Development of specifications for each component to include quantities involved and base-weight unit prices. Specifications must be exact to avoid the risk of varying interpretation by different respondents.

- Selection of a sub-sample of subcontractors and general contractors in the appropriate geographic areas from whom prices are collected. An important goal is to select contractors who are actively engaged in building sample components and can report price quotes based on recent experience. Some respondents might be able to supply quotes on components included in more than one model.

- Collection of periodic reports for a sample of these components from subcontractors. These should be based on current prices they charge (including overheads and profit) for the component they supply. Price collection may be done by telephone or mail, generally after an initial personal visit to gain co-operation and discuss reporting problems. The prices of electrical and mechanical equipment can be obtained from manufacturers of the equipment.

- Calculation of a price index for the construction as a weighted combination of these component prices. This is done by multiplying new price quotations by base period weights, and comparing the result to base period model prices.

- Development and implementation of an ongoing process of index review to revise the list of model projects, weights, component items, respondents, etc.

3.5 Consumer Price Index (CPI)

The consumer price index measures, by comparing in time, the price variation of a basket of goods and services purchased by the householders in a certain reference period. It is provided that the index shall reflect only the price movements by taking care of the quantity and quality changes of every material in the basket of good and service (SSI Turkey, 2002).

On the other hand, the Statistics Directorate of the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996) states that CPIs are designed to measure changes over time in average retail prices of a fixed basket of goods and services taken as representing the consumption habits of households.

The consumer price index is used for various purposes. The most important ones are listed by the Statistics Directorate of the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996) as the following:

- Measurement of the inflation in macro-economic sense and comparison of them with other countries.
- Determination of the economic politics of the governments.
- Adjustment of the wages and costs.
- Purification of any value data from the inflation.
- To be an indicator for the national accounting
- To be an indicator for price analysis
- Orientation of the commercial facilities
- To be an indicator for the retail price and the increase in rent.

The 2003 base year consumer price index calculated by Prime Ministry State Institute of Statistics covers all of the consumption expenses in Turkey, without considering the citizen of the people making these expenses and whether they live in domestic. In the coverage, any differentiation according to the income groups of the population and the geography regions is not applied.

3.6 Producer Price Index (PPI)

SSI Turkey (2002) defines the Producer Price Index as the price index which measures the price differences by comparing the producer prices of the products manufactured for the country economy in a certain reference period and being subject to domestic sale. The producer price is the selling price in advance of the products manufactured in the home country excluding VAT and similar taxes. For the producer price indices, the first-hand selling prices of the products, which the producers activating in the fields of agriculture, hunting, forestry and fishery grow and present to the market, are monitored. These prices related to the agricultural sector are named as the Prices Earned by the Producer. The prices of the products related to the industrial sector, on the other hand, are received directly from the producer firms.

Another definition comes from the Statistics Directorate of the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996), which dictates that PPIs provide measures of average movements of prices received by the producers of commodities. In principle, PPIs exclude transport costs and consumption taxes. Producer price indices are not a measure of average price levels, or of the costs of production. Moreover, PPIs do not include commercial mark-ups. Though the scope of PPIs varies, they are generally calculated on the basis of the total turnover of a definable industry such as manufacturing, agriculture, or mining (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996).

The PPI being used up to the current period was a mixed price index, which was calculated by obtaining the prices of the materials manufactured in the home country partially from the producers and partially from the mediators who do not make sales and who are engaged with wholesale, and where the prices included the taxes for the consumers and the margins of the wholesalers (SSI Turkey, 2002). The Producer Price Index comes now for common use, both to establish a more meaningful index which measures the price differences during the production period against the Consumer Price Index which measures the price differences during the consumption period, and to provide the harmony and to enable the comparison with the international indices.

The basic difference between the two indices appears among the units where the prices are gathered. The prices for the PPI are also gathered from the wholesale selling spots (from vegetable, fruit and fish markets) in addition to the producers. VAT and similar taxes are included in the prices of the wholesale goods. For the producer price indices, the basic point is to gather the prices form the producers and the prices of the products are the domestic selling prices in advance, excluding VAT and the similar taxes.

The producer price index is used for various purposes, most important of which are mentioned by the Statistics Directorate of the OECD (1994 (a), 1996, 1994 (b)) and EUROSTAT (1995, 1996) as the following:

- Following the price movements in inflation and economy.
- Determination of the economic politics of the governments.
- Adjustment of the wages and costs.
- Production and productivity calculations.
- Accounting calculations.
- Studies related to the price analysis
- Investment decisions.

3.7 Building Construction Cost Index (BCCI)

The State Institute of Statistics calculates a quarterly building construction cost index based on the standard factor method. The purpose of the index is to identify changes in the cost of input items used in construction projects. The index covers the construction of houses and apartments, shops and commercial buildings, medical buildings, schools and cultural buildings, and administrative buildings. In total these categories cover more than 90 per cent of construction activity in Turkey. In terms of geographic area covered, the index covers all of Turkey.

Included in the index are costs of materials, labor and machinery. No taxes are included in the prices used in the calculation of the index, but the prices are net of discounts. Most of the cost data used are obtained through surveys of construction and other enterprises as well as from price lists. The data are collected from 24 provinces which have been chosen to represent all the regions of Turkey. Price quotations are obtained for each of the items costed from three establishments in each province. In total, 295 items are priced from around 1.300 suppliers to construction firms (SSI Turkey, 2002).

The selection of items for inclusion in the index was made after extensive consultation with interested bodies, including the Finance and Industry Statistics Divisions within the State Institute of Statistics, the Chamber of Civil Engineers and of Architects, trade unions and a number of other institutions and associations. With the help of the Turkish Scientific and Technical Resource Institution and their publication Construction Unit Price Analysis, the items were selected and weights determined through detailed examination of bills of quantities for a sample of current projects representative in terms of regional distribution and project type of construction activity within the scope of the index. The index is calculated quarterly according to the Laspeyres formula and has base period 1991=100 (Sources and Methods – Construction Price Indices, OECD, 1994 (a), 1996, 1994 (b) & EUROSTAT, 1995, 1996).

The index results are published by the State Institute of Statistics in the publication Quarterly Building Construction Cost Index. In addition to the aggregate results, separate indices are published for materials, machinery and labor costs, as well as for apartments, houses, and other construction. The methodology used in the compilation of the index is published in Methodology of the Building Construction Cost Index. Regional results as well as national indices for Turkey are presented.

3.8 Cost Index (CI)

The Ministry of Public Works and Settlement publishes every year an index to be used to escalate the past costs of construction projects in Turkey. The subject index is calculated based on the rates of increase in the prices of certain material, labor and equipment groups. Cost Index can also be defined as the weighted average of the rates of increase in these certain groups of material, labor and equipment.

CHAPTER IV

METHODOLOGY AND DATA ANALYSIS

4.1 Introduction

Construction cost indices have always been used to assess the variations in labor and material costs (Wang and Mei, 1998). In other words, they represent the variations in the costs of material and labor, which form in general the sub-items of construction costs. Several cost indices are calculated and published by governmental organizations to be used for several purposes; whereas various studies are conducted for different classes of constructional structures to achieve more accurate cost indices to be used specifically for that type of constructions. This kind of studies consider the weight of the material and labor costs included in that specific type of construction and the price variations for these material and labor costs are examined to calculate such kind of specific construction cost indices.

This study aims to compare the existing cost indices as well as new alternative cost indices in terms of their adequacy for the representation of variations in the building costs in Turkey. This section presents the steps of calculating several cost indices using the data of building projects compiled from several Turkish contractors. In addition, the produced price indices will be compared with those published by governmental organizations in Turkey; and thus, it will be possible to evaluate the adequacy of these developed indices. Finally, the most adequate cost index to be used for building projects will be selected. Moreover, statistical methods will be used to predict the future values of selected cost indices and advantages of use of such kind of indices will be discussed.

4.2 Data Collection

The data of 23 building projects (residential, hotel, office and hospital), out of which 14 were public and 9 were private and which were executed within the time frame 1994-2004, were compiled from several Turkish contractors. These data actually covered the contract date, total contract price for civil scope and total closed area of these projects. Table 4.1 lists the projects, classifying them into groups in terms of their types and presents the contract dates of the same.

Table 4.1: List of projects

NO	PROJECT NAME	TYPE	CONTRACT DATE
1	Project 1	RESIDENTIAL	06.09.1994
2	Project 2	OFFICE	01.10.1995
3	Project 3	HOTEL	01.08.1997
4	Project 4	HOTEL	01.10.1997
5	Project 5	HOTEL	01.02.1998
6	Project 6	RESIDENTIAL	01.04.1998
7	Project 7	RESIDENTIAL	07.05.1998
8	Project 8	HOSPITAL	01.09.1999
9	Project 9	RESIDENTIAL	24.04.2000
10	Project 10	RESIDENTIAL	13.05.2000
11	Project 11	HOSPITAL	07.11.2000
12	Project 12	OFFICE	08.11.2000
13	Project 13	OFFICE	07.02.2001
14	Project 14	RESIDENTIAL	06.09.2001
15	Project 15	HOSPITAL	01.04.2002
16	Project 16	OFFICE	10.05.2002
17	Project 17	OFFICE	07.10.2002
18	Project 18	OFFICE	01.11.2002
19	Project 19	RESIDENTIAL	01.01.2003
20	Project 20	OFFICE	01.03.2003
21	Project 21	HOSPITAL	08.09.2003
22	Project 22	OFFICE	21.11.2003
23	Project 23	RESIDENTIAL	01.06.2004

The contract prices (see Table 4.2) covered only the civil scope, excluding electrical and mechanical works, in parallel with the purpose of the study which is to achieve a price index for the civil costs. The term cost anywhere in this study refers to the contract price for the civil works of a building project. However, VAT was excluded from these prices. On the other hand, closed areas of the buildings, in the range of 2,000 – 92,000 m^2 (see Figure 4.1), were used to obtain the unit costs, represented by *UC* in TL/m^2.

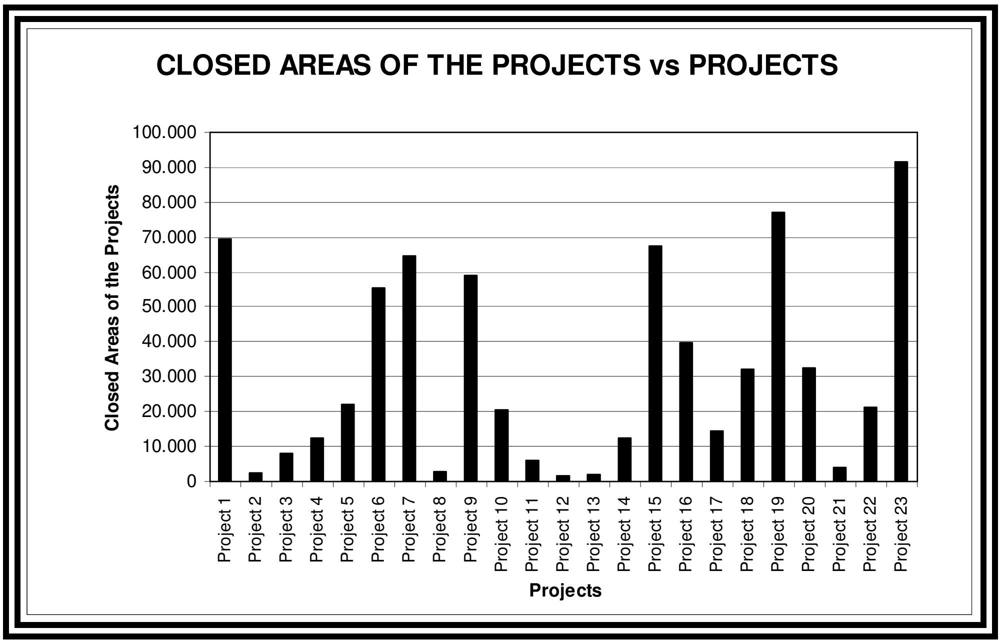

Figure 4.1: Closed Areas of the Projects

The contract prices were in two different currencies, Turkish Lira (TL) for 16 projects and United States Dollar (USD) for 7 projects. The contract prices in USD were converted to TL by using the buying exchange rate published by the Central Bank of Turkey at the date of contract for each project.

Table 4.2: Unit Costs of the Projects

NO	PROJECT NAME	TL/m^2
1	Project 1	3.999.566
2	Project 2	11.767.566
3	Project 3	63.008.464
4	Project 4	27.922.055
5	Project 5	77.766.697
6	Project 6	36.202.903
7	Project 7	37.096.930
8	Project 8	156.981.219
9	Project 9	69.263.961
10	Project 10	222.981.829
11	Project 11	73.857.247
12	Project 12	114.603.108
13	Project 13	170.535.291
14	Project 14	139.786.060
15	Project 15	257.999.135
16	Project 16	167.726.549
17	Project 17	363.749.680
18	Project 18	236.991.800
19	Project 19	106.077.192
20	Project 20	214.541.316
21	Project 21	235.264.803
22	Project 22	219.664.566
23	Project 23	216.810.253

4.3 Identification of Price Indices

The price indices can be classified into two groups, as available price indices and produced price indices.

4.3.1 Available Price Indices

The first group of the price indices was composed of the indices which have already been calculated by several governmental organizations and a web survey was conducted to collect the values of the these price indices available for the time frame 1994-2004. In this study, the Consumer Price Index (CPI), the Producer Price Index (PPI), the Cost Index (CI) and the Building Cost Index (BCI) were considered for the comparison purposes and their corresponding annual values were gathered from the relevant web sites and publications. However, the values of BCI were quarter based and the average of quarters was calculated to obtain the annual values for each corresponding year.

4.3.2 Produced Price Indices

Different from the available price indices mentioned as the first group, four more indices were calculated by using the unit rates published by the Ministry of Public Works and Settlement for the three indices and the building cost indices published by the State Statistic Institute for the other one, and the indices in this second group were called as the *produced price indices*. The following sections provide detailed explanations regarding the calculation methods and steps of these indices.

4.3.2.1 Produced Building Price Index 1 ($PBPI_1$)

The hint behind the calculation of produced price indices was to search for common work items within the projects considered for this study. It was not an unexpected result to find that the steel, formwork and concrete works were all common through these building projects, when the detailed bill of quantities belonging to the same were examined. Yet, combination of these works would cover a significant amount of the total cost of the projects, when compared to the other work items. In addition, the purpose in this step was to establish a price index based upon structural works. As such, this price index was calculated on the basis of the following:

- the average weights of these work items [$(W_{steel})_{ave}$, $(W_{formwork})_{ave}$ and $(W_{concrete})_{ave}$]; where $(W_{steel})_{ave}$ is the average weight for steel works; $(W_{formwork})_{ave}$ is the average weight for formwork works; and $(W_{concrete})_{ave}$ is the average weight for concrete works), and,

- using the annual unit rates published by the MPWS during the time frame 1989-2004 corresponding to work items related with ***steel, formwork*** and ***concrete works*** [$(UR_{steel})_i$, $(UR_{formwork})_i$ and $(UR_{concrete})_i$; where i is the year; (UR_{steel}) is the annual unit rate for steel; $(UR_{formwork})$ is the annual unit rate for formwork; and $(UR_{concrete})$ is the annual unit rate for concrete, which were afterwards converted to indices which were dimensionless numbers [$(I_{steel})_i$, $(I_{formwork})_i$ and $(I_{concrete})_i$; calculated based upon the equations 4.2, 4.3 and 4.4]

$PBPI_1$ was in the following form:

$$(PBPI_1)_i = \begin{bmatrix} (W_{steel})_{ave} * (I_{steel})_i + (W_{formwork})_{ave} * (I_{formwork})_i + \\ (W_{concrete})_{ave} * (I_{concrete})_i \end{bmatrix} \qquad [4.1]$$

Equation [4.1] represents the form of $PBPI_1$. To be integrated into this index equation, the unit rates of each of steel, formwork and concrete works for the corresponding years were converted to dimensionless numbers by assigning the value of 1 for base year 1989 and by dividing the values of the other years by the value of the unit rate of the base year.

$$(I_{steel})_i = \frac{(UR_{steel})_i}{(UR_{steel})_{baseyear}} \quad [4.2]$$

$$(I_{formwork})_i = \frac{(UR_{formwork})_i}{(UR_{formwork})_{baseyear}} \quad [4.3]$$

$$(I_{concrete})_i = \frac{(UR_{concrete})_i}{(UR_{concrete})_{baseyear}} \quad [4.4]$$

The first step of calculation of this index was to calculate the average weights of the steel, formwork and concrete works [$(W_{steel})_{ave}$, $(W_{formwork})_{ave}$ and $(W_{concrete})_{ave}$]. These were calculated in the following steps:

1) The total costs for each of these items [$(C_{steel})_i$, $(C_{formwork})_i$ and $(C_{concrete})_i$] were determined from the detailed bill of quantities.

2) These total costs for each item of work were divided by the summation of these to obtain the weights for each year as per the equations 4.5, 4.6 and 4.7:

$$(W_{steel})_i = \frac{(C_{steel})_i}{(C_{steel})_i + (C_{formwork})_i + (C_{concrete})_i} \quad [4.5]$$

$$(W_{formwork})_i = \frac{(C_{formwork})_i}{(C_{steel})_i + (C_{formwork})_i + (C_{concrete})_i} \quad [4.6]$$

$$(W_{concrete})_i = \frac{(C_{concrete})_i}{(C_{steel})_i + (C_{formwork})_i + (C_{concrete})_i} \quad [4.7]$$

Where i is the project number; W_{steel} is the weight of total cost of steel works for a project; $W_{formwork}$ is the weight of total cost of formwork works for a project; $W_{concrete}$ is the weight of total cost of concrete works for a project; C_{steel} is the total cost of steel works in a project; $C_{formwork}$ is the total cost of formwork works in a project; and $C_{concrete}$ is the total cost of concrete works in a project. The following equation also would hold:

$$(W_{steel})_i + (W_{formwork})_i + (W_{concrete})_i = 1 \quad [4.8]$$

It should be mentioned that these weights **could only** be calculated for the projects of which detailed cost analyses were available. The next step was to take the average of the weights of these work items to calculate a common and final weight representing the steel, formwork and concrete works separately.

$$(W_{steel})_{ave} = \frac{\sum (W_{steel})_i}{n} \quad [4.9]$$

$$(W_{formwork})_{ave} = \frac{\sum (W_{formwork})_i}{n} \quad [4.10]$$

$$(W_{formwork})_{ave} = \frac{\sum (W_{formwork})_i}{n} \quad [4.11]$$

Where n is the number of projects of which detailed cost analyses were available; $(W_{steel})_{ave}$ is the average weight for steel works; $(W_{formwork})_{ave}$ is the average weight for formwork works; $(W_{concrete})_{ave}$ is the average weight for concrete works; and i is the project number.

As a summary, $PBPI_1$ was calculated based upon the following work items:

- Steel works
- Formwork works
- Concrete works

These average weights, $(W_{steel})_{ave}$, $(W_{formwork})_{ave}$ and $(W_{concrete})_{ave}$, as presented in Table 4.3, were used together with the indices $(I_{steel})_i$, $(I_{formwork})_i$ and $(I_{concrete})_i$, as presented in Table 4.4, to calculate the $PBPI_1$ as illustrated in equation [4.1].

Table 4.3: Average Weights for $PBPI_1$

$PBPI_1$	$(W_{steel})_{ave}$	$(W_{formwork})_{ave}$	$(W_{concrete})_{ave}$
	0,343	0,348	0,309

Table 4.4: Index values for $PBPI_1$

Years	I_{steel}	$I_{concrete}$	$I_{formwork}$
1989	1,00	1,00	1,00
1990	1,41	1,70	1,75
1991	1,84	3,02	2,81
1992	3,05	4,92	4,70
1993	5,47	7,52	8,01
1994	8,67	11,96	13,76
1995	21,07	23,96	30,33
1996	33,01	44,32	60,53
1997	59,13	102,78	117,74
1998	114,07	158,22	196,12
1999	151,03	237,33	319,85
2000	255,57	379,05	475,58
2001	329,04	493,42	598,35
2002	609,83	741,49	1.043,98
2003	925,23	967,04	1.369,25
2004	1.076,76	1.083,82	1.568,63

4.3.2.2 Produced Building Price Index 2 ($PBPI_2$)

$PBPI_2$ was calculated with the same method through which $PBPI_1$ was calculated. However, different from $PBPI_1$, this index was calculated based upon the weights and indices derived from the unit rates of several work items, in addition to steel, formwork and concrete works, since the purpose in this step was to establish a price index formed with the contribution of both structural works and architectural works. Equation 4.12 represents the form in which $PBPI_2$ was calculated:

$$(PBPI_2)_i = \begin{bmatrix} (W_{steel})_{ave} * (I_{steel})_i + (W_{formwork})_{ave} * (I_{formwork})_i + \\ (W_{concrete})_{ave} * (I_{concrete})_i + (W_{screed})_{ave} * (I_{screed})_i + \\ (W_{lev.concrete})_{ave} * (I_{lev.concrete})_i + (W_{\text{int}.plaster})_{ave} * (I_{\text{int}.plaster})_i + \\ (W_{heatins.})_{ave} * (I_{heatins.})_i + (W_{plasticpa\text{int}})_{ave} * (I_{plasticpa\text{int}})_i \end{bmatrix} \quad [4.12]$$

Where $(W_{steel})_{ave}$ is the average weight for steel works; $(W_{formwork})_{ave}$ is the average weight for formwork works; $(W_{concrete})_{ave}$ is the average weight for concrete works; $(W_{screed})_{ave}$ is the average weight for screeding works; $(W_{lev.concrete})_{ave}$ is the average weight for leveling concrete works; $(W_{int.plaster})_{ave}$ is the average weight for interior plastering works; $(W_{heatins})_{ave}$ is the average weight for heat insulation works; $(W_{plasticpaint})_{ave}$ is the average weight for plastic paint works; (I_{steel}), $(I_{formwork})$, $(I_{concrete})$, (I_{screed}), $(I_{lev.concrete})$, $(I_{int.plaster})$, $(I_{heatins})$ and $(I_{plasticpaint})$ are the corresponding index values as calculated in the same way with $PBPI_1$; and *i* is the project number.

$PBPI_2$ was calculated based upon the following work items:

- Steel works
- Formwork works
- Concrete works
- Screeding works
- Leveling concrete works
- Interior plastering works

- Heat insulation works

- Plastic paint works

The average weights for these work items were calculated in the same way as done through equations 4.5, 4.6, 4.7, 4.9, 4.10 and 4.11 (see Table 4.5), by also considering the total costs for additional architectural work items mentioned above.

Table 4.5: Average Weights for $PBPI_2$

$PBPI_2$	$(W_{steel})_{ave}$	$(W_{formwork})_{ave}$	$(W_{concrete})_{ave}$	$(W_{screed})_{ave}$
	0,304	0,290	0,257	0,018
	$(W_{lev.concrete})_{ave}$	$(W_{int.plaster})_{ave}$	$(W_{heat\ ins.})_{ave}$	$(W_{plastic\ paint})_{ave}$
	0,026	0,026	0,007	0,072

The indices in Equation 4.12 were calculated in parallel with the same logic as applied for equations 4.2, 4.3 and 4.4. Table 4.6 lists the values of these indices for each work item corresponding to the time frame 1989-2004.

Table 4.6: Index values for $PBPI_2$

Years	I_{steel}	$I_{concrete}$	$I_{formwork}$	I_{screed}	$I_{lev.concrete}$	$I_{int.plaster}$	$I_{heat\ ins.}$	$I_{plastic\ paint}$
1989	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
1990	1,41	1,70	1,75	1,69	1,60	1,68	1,33	1,33
1991	1,84	3,02	2,81	2,88	2,74	2,60	2,17	1,67
1992	3,05	4,92	4,70	5,00	4,80	4,14	7,73	2,62
1993	5,47	7,52	8,01	8,39	8,09	6,82	11,59	4,22
1994	8,67	11,96	13,76	14,66	14,31	11,75	12,18	6,97
1995	21,07	23,96	30,33	29,27	28,01	22,80	19,91	16,00
1996	33,01	44,32	60,53	55,43	52,87	43,09	44,12	28,89
1997	59,13	102,78	117,74	116,65	112,85	85,90	67,31	53,56
1998	114,07	158,22	196,12	205,64	202,21	145,04	142,72	93,33
1999	151,03	237,33	319,85	342,79	339,40	237,99	178,87	149,33
2000	255,57	379,05	475,58	537,76	539,16	401,77	286,19	261,33
2001	329,04	493,42	598,35	714,93	725,17	521,86	385,87	311,11
2002	609,83	741,49	1.043,98	1.178,05	1.169,77	830,57	767,53	622,22
2003	925,23	967,04	1.369,25	1.596,08	1.605,58	1.134,03	1.028,98	888,89
2004	1.076,76	1.083,82	1.568,63	1.839,71	1.863,88	1.325,35	1.047,28	1.000,00

4.3.2.3 Produced Building Price Index 3 ($PBPI_3$)

$PBPI_3$ was calculated based upon the following work items (see Equation 4.13):

- Interior plastering works
- Heat insulation works

- Plastic paint works

$$(PBPI_3)_i = \begin{bmatrix} (W_{int.plaster})_{ave} * (I_{int.plaster})_i + (W_{heatins.})_{ave} * (I_{heatins.})_i + \\ (W_{plasticpaint})_{ave} * (I_{plasticpaint})_i \end{bmatrix} \quad [4.13]$$

Where $(W_{int.plaster})_{ave}$ is the average weight for interior plastering works; $(W_{heatins})_{ave}$ is the average weight for heat insulation works; $(W_{plasticpaint})_{ave}$ is the average weight for plastic paint works; $(I_{int.plaster})$, $(I_{heatins})$ and $(I_{plasticpaint})$ are the corresponding index values as calculated in the same way with $PBPI_1$ and $PBPI_2$; and *i* is the project number.

The calculated average weights and indices are presented in Tables 4.7 and 4.8, respectively.

Table 4.7: Average Weights for $PBPI_3$

$PBPI_3$	$(W_{int.plaster})_{ave}$	$(W_{heat\ ins.})_{ave}$	$(W_{plastic\ paint})_{ave}$
	0,026	0,007	0,072

Table 4.8: Index values for $PBPI_3$

Years	$I_{int.plaster}$	$I_{heat\ ins.}$	$I_{plastic\ paint}$
1989	1,00	1,00	1,00
1990	1,68	1,33	1,33
1991	2,60	2,17	1,67
1992	4,14	7,73	2,62
1993	6,82	11,59	4,22
1994	11,75	12,18	6,97
1995	22,80	19,91	16,00
1996	43,09	44,12	28,89
1997	85,90	67,31	53,56
1998	145,04	142,72	93,33
1999	237,99	178,87	149,33
2000	401,77	286,19	261,33
2001	521,86	385,87	311,11
2002	830,57	767,53	622,22
2003	1.134,03	1.028,98	888,89
2004	1.325,35	1.047,28	1.000,00

4.3.2.4 Produced Building Price Index 4 ($PBPI_4$)

Different from $PBPI_1$, $PBPI_2$ and $PBPI_3$, the price index $PBPI_4$ was established based upon the building cost indices published by the State Statistic Institute. For the calculation purposes of this price index, several common work items regarding only architectural works (paint, polish and insulation materials, glazing materials and door and window metal parts) were selected throughout the projects and sub-indices, corresponding to these work items, which form these published building cost indices when summed up, were used to calculate $PBPI_4$ as per the Equation 4.14. The detailed analysis of the prices of the building projects were not available in parallel with the entire set of sub-indices, which was the fact to limit the number of sub-indices to be used for analysis. In other words, paint, polish and insulation materials, glazing materials and door and window metal parts were the only sub-indices corresponding directly to the available price details of the building projects.

$$(PBPI_4)_i = \begin{bmatrix} (W_{paint,pol.\&ins.mat})_{ave} * (I_{paint,pol.\&ins.mat})_i + \\ (W_{glazingmat.})_{ave} * (I_{galazingmat.})_i + \\ (W_{door\&wind.met.p})_{ave} * (I_{door\&wind.met.p})_i \end{bmatrix} \quad [4.14]$$

Where $(W_{paint,pol.\&ins.mat.})_{ave}$ is the average weight for paint, polish and insulation materials; $(W_{glazing\ mat.})_{ave}$ is the average weight for glazing materials; $(W_{door\&wind.met.p})_{ave}$ is the average weight for door and window metal parts; $(I_{paint,pol.\&ins.mat.})$, $(I_{glazing\ mat})$ and $(I_{door\&wind.met.p})$ are the corresponding index values as published by the State Statistics Institute and as presented in Table 4.10; and i is the project number.

As a summary, $PBPI_4$ was calculated based upon the following work items (see Equation 4.13):

- paint, polish and insulation materials
- glazing materials
- door and window metal parts

Table 4.9 presents the average weights for these selected work items.

Table 4.9: Average Weights for $PBPI_4$

$PBPI_4$	$(W_{paint,pol.\&ins.mat.})_{ave}$	$(W_{glazing\ mat.})_{ave}$	$(W_{door\&wind.met.p})_{ave}$
	0,372	0,244	0,384

On the other hand, in Table 4.10, the index values for these work items are listed for the time frame 1994-2004.

Table 4.10: Index values for $PBPI_4$

Years	$I_{paint,pol.\&ins.mat.}$	$I_{glazing\ mat.}$	$I_{door\&wind.met.p}$
1994	100	100	100
1995	168	199	182
1996	307	337	299
1997	655	587	559
1998	1.208	1.001	978
1999	1.911	1.574	1.476
2000	2.910	2.317	2.131
2001	5.069	4.153	3.682
2002	7.212	5.878	5.432
2003	8.215	7.109	6.737
2004	8.581	7.537	7.608

4.3.2.5 Summary list for the Price Indices

Table 4.11 presents the summary as a list of the values of the available price indices (CPI, PPI, CI and BCI) and produced price indices ($PBPI_1$, $PBPI_2$, $PBPI_3$ and $PBPI_4$), calculated for the time frame 1994-2005, in accordance with the methods described in the previous sections.

Table 4.11: Values for Available and Produced Price Indices for the time frame 1994-2004

Indices / Year	BCI	CPI	PPI	CI	$PBPI_1$	$PBPI_2$	$PBPI_3$	$PBPI_4$
1994	598,00	99,43	100,00	104,59	11,39	11,17	8,54	100,00
1995	1.007,00	188,04	186,03	47,54	24,94	24,29	17,99	180,96
1996	1.781,00	339,22	327,28	26,34	45,45	44,33	33,54	311,32
1997	3.385,00	629,88	595,26	13,53	92,45	89,64	62,68	601,66
1998	5.888,00	1.163,03	1.022,42	7,84	154,81	151,42	109,85	1.069,17
1999	9.186,00	1.917,45	1.564,93	5,06	233,28	230,13	173,77	1.661,79
2000	13.126,00	2.970,43	2.369,85	3,06	366,59	364,80	298,49	2.466,05
2001	20.543,00	4.586,34	3.830,33	2,50	469,54	467,28	369,51	4.312,83
2002	27.914,00	6.648,55	5.749,60	1,51	789,92	792,14	684,98	6.203,47
2003	33.855,00	8.330,39	7.219,36	1,16	1.077,11	1.084,77	960,56	7.377,98
2004	38.797,00	9.212,10	8.020,14	1,00	1.231,34	1.240,10	1.085,37	7.952,79

4.4 Regression Analysis

The next step was to select a method to quantify how much the unit costs were explained by the indices mentioned up to here, each of which was considered as the independent variable for the models driven. Regression analysis was selected and was used as the method for this purpose. The purpose in this section of the study was to perform regression analyses by using each of the price indices as an independent variable separately and the unit costs of the projects as the dependent variable. Regarding the concept of regression analysis, one can use it to identify the relationship between a dependent variable and independent variables. In other words, the parametric results of a regression analysis indicate the quantity of the relationship between the independent variables and the dependent variable involved in the process. Ostwald (2001, p.146-148) states that in regression, on the basis of sample data, the value of a dependent variable y is to be found corresponding to a given value of a variable x. This is determined from a least-squares equation that fits the sample data. If the variable x is time, then the data show the values of y at various times, and the equation is known as a time series. A regression line or a curve y on x or the response function on time is frequently called a trend line and is used for prediction and forecasting. Thus, regression refers to average relationship between variables.

"The notion of fitting a curve to a set of sufficient points is essentially the problem of finding the parameters of the curve. The best-known method is that of least squares (regression). Since the desired curve or equation is to be used for estimating or prediction purposes, the curve or equation should be so modeled as to make the errors of estimation small. An error of estimation means the difference between an observed value and the corresponding fitted curve value for the specific value of x. It will not do require that the sum of these differences or errors to be as small as possible. It is a requirement that the sum of absolute value of the errors be as small as possible. However, sums of absolute values are not convenient mathematically. The difficulty is avoided by requiring that the sum of the squares of the errors be minimized. If this procedure is followed, the values of parameters give what is known as the best curve in the sense of least-squares difference (Ostwald, 2001, p.146-148)".

In this step of regression process, linear regression analyses were performed for each of the indices being the independent variables and the unit cost being the dependent variable. As stated previously, the aim of this step was to measure and compare the level of linear fit between the cost indices developed and cost data collected for a time frame of 11 years. The prediction performance of the regression models with price indices as independent variables to predict building costs will also be compared. This comparison would lead to the selection of the adequate cost index for escalation of building construction costs.

Before the regression analysis, the unit costs of the projects were plotted against the price indices, of which values for the time frame 1994-2004 are presented in Table 4.11. Figures 4.2 to 4.9 illustrate clear images for the relationships between these parameters. These plots indicate that linear relations were present between the subject parameters (unit costs and price indices).

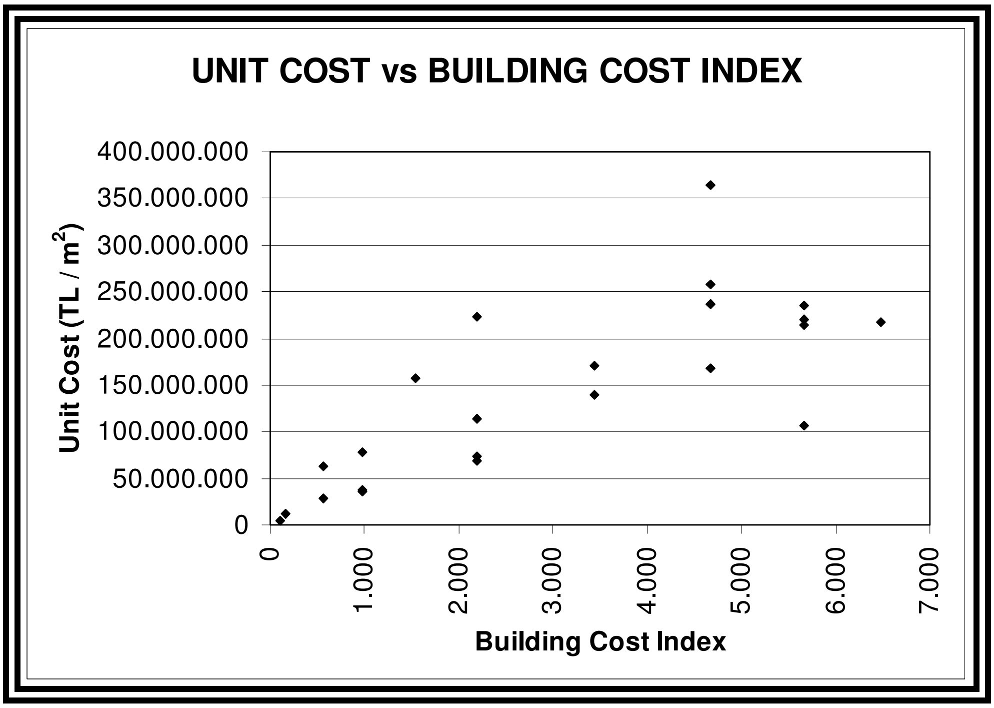

Figure 4.2: Unit Cost vs. Building Cost Index

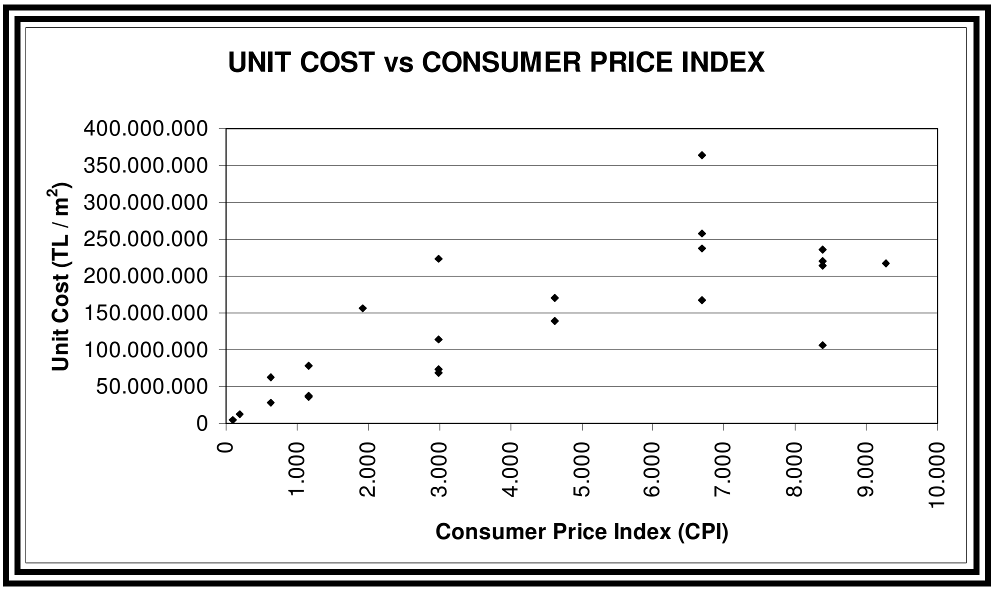

Figure 4.3: Unit Cost vs. Consumer Price Index

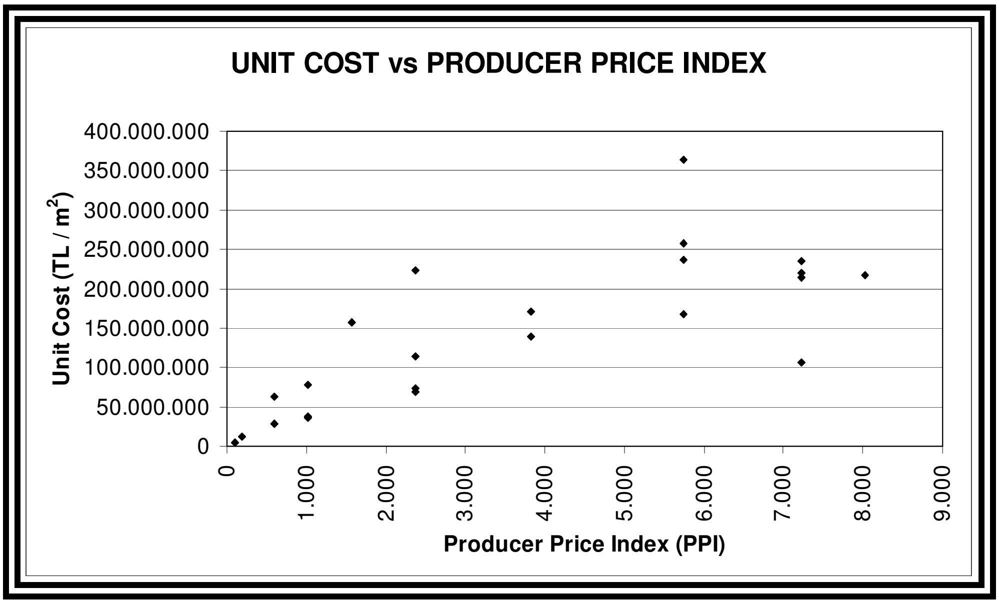

Figure 4.4: Unit Cost vs. Producer Price Index

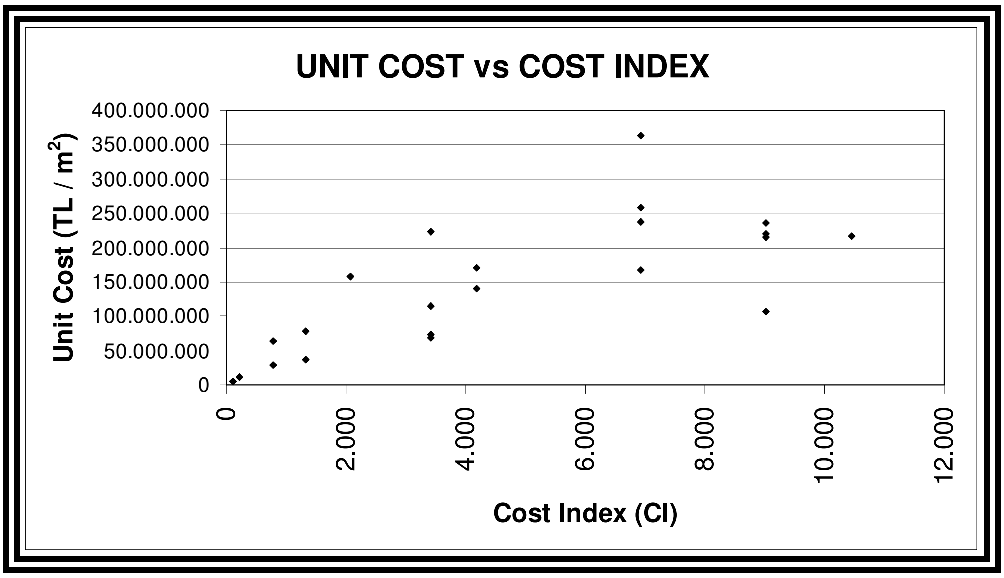

Figure 4.5: Unit Cost vs. Cost Index

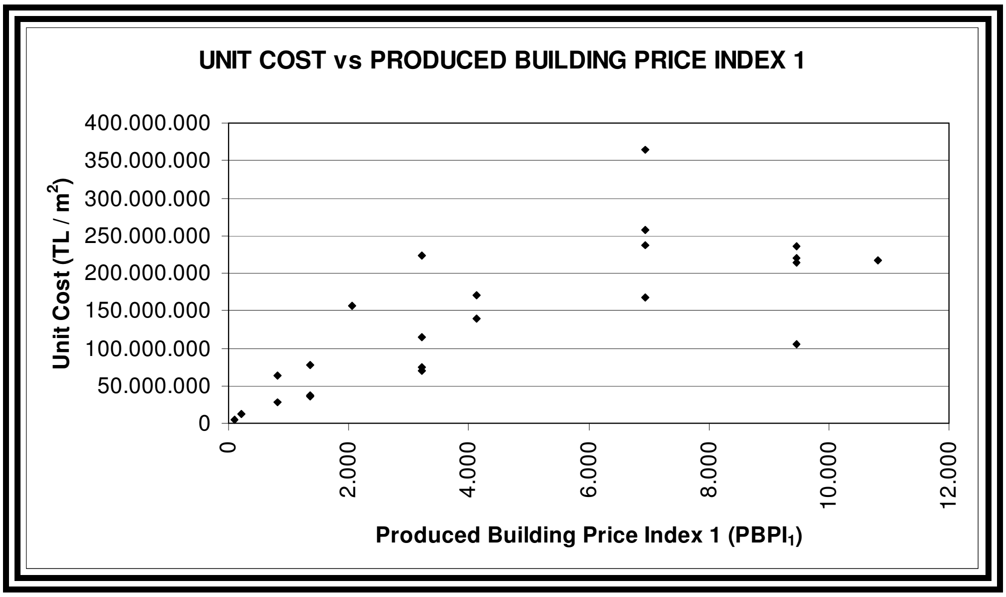

Figure 4.6: Unit Cost vs. Produced Building Price Index 1

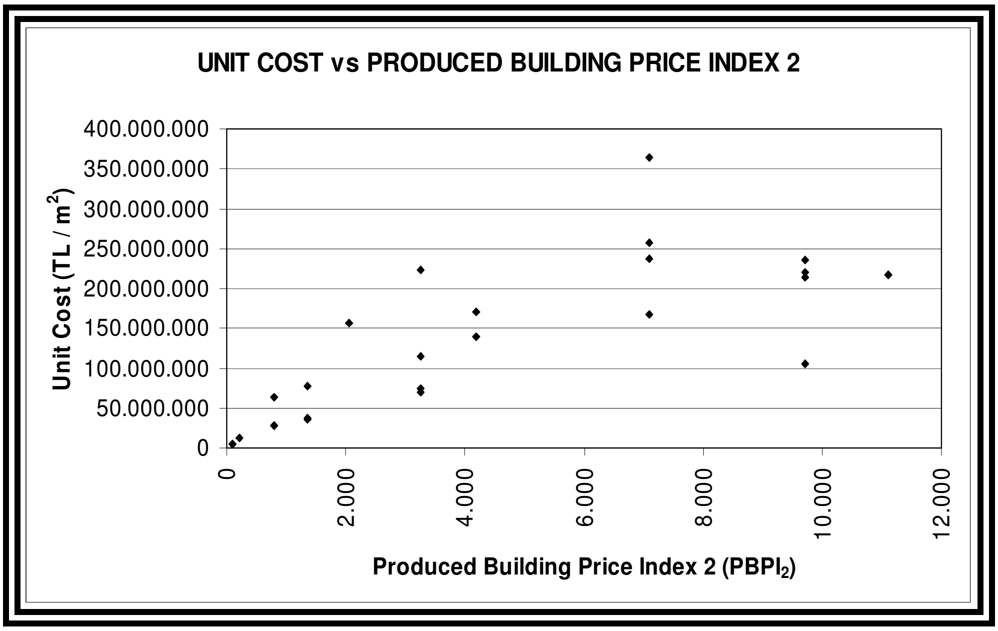

Figure 4.7: Unit Cost vs. Produced Building Price Index 2

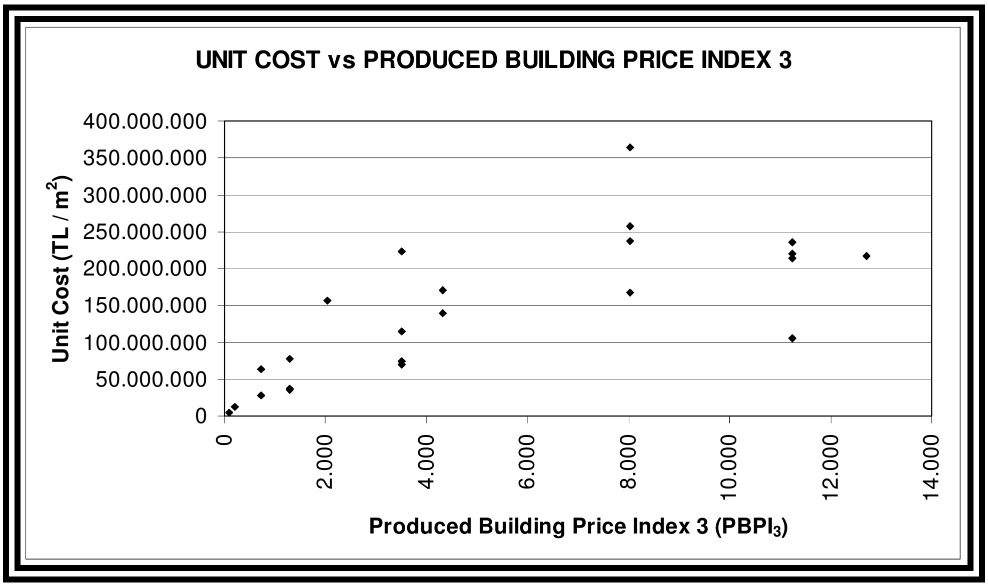

Figure 4.8: Unit Cost vs. Produced Building Price Index 3

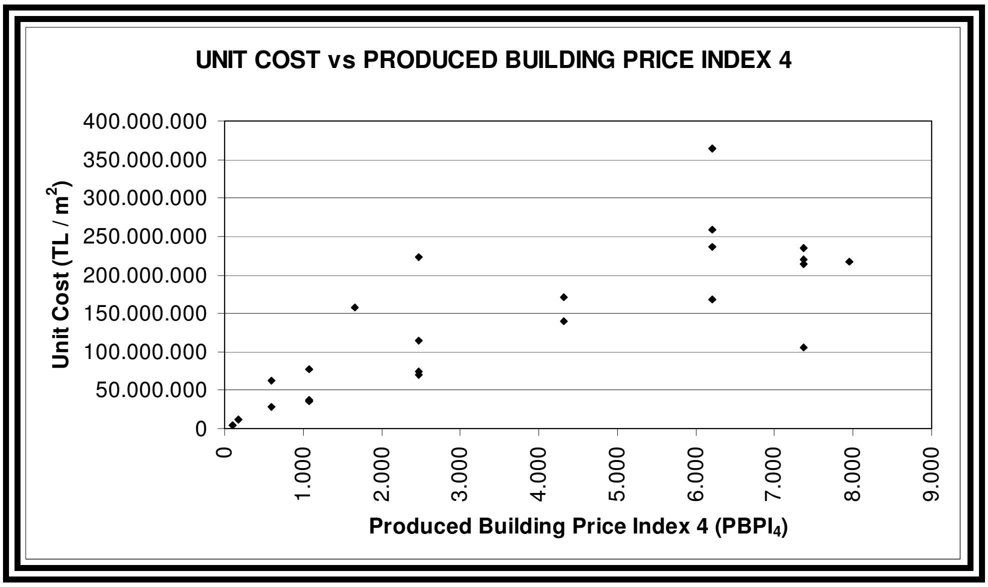

Figure 4.9: Unit Cost vs. Produced Building Price Index 4

However, to quantify these relationships, regression analyses were performed, with the results presented in Table 4.14.

Table 4.12: Closeness of Fit of the models RM1.1 to RM1.8

Regression Model	Independent Variable	P-value	R^2
RM1.1	**BCI**	0,0000113	0,609
RM1.2	**CPI**	0,0000157	0,597
RM1.3	**PPI**	0,0000190	0,589
RM1.4	**CI**	0,0000299	0,572
RM1.5	**$PBPI_1$**	0,0000511	0,550
RM1.6	**$PBPI_2$**	0,0000537	0,548
RM1.7	**$PBPI_3$**	0,0000728	0,535
RM1.8	**$PBPI_4$**	0,0000098	0,614

Two regression statistics, significance level (*P* value, giving an indication of the significance of the variables included in the model) and coefficient of determination (R^2, which gives a measure of the variability explained by the model) were listed in Table 4.14. R^2 also gives a measure for the variability explained by the models. The R^2 values for the models were between 0.55 and 0.62 as the only independent variable used in these models was the price index. This variable only explains the cost variations due to the inflation. However, there are several other factors such as quality, number of floors, techniques and methods used, and also factors related to management that were not included in these models. Therefore, the models only explain the variations in costs related to inflation. The model with a higher R^2 value is expected to have a less P-value for the variable. RM1.8 had the highest value of R^2, being 0.614.

R^2 (Coefficient of Determination) can be also calculated manually by Equation 4.16 rather than using the Microsoft Office Excel.

$$R^2 = \frac{S_{yy} - SSE}{S_{yy}} \quad [4.16]$$

Where S_{yy} is the total variability in y-values, SSE is the unexpected variability and they can be calculated by the Equations 4.17 and 4.18 respectively.

$$S_{yy} = \sum (y - \mu_y)^2 \quad [4.17]$$

$$SSE = \sum (y - \hat{y})^2 \quad [4.18]$$

Where μ_y is the mean value of the y-values and $\hat{y}$ is the estimated y value and it can be calculated by the Equation 4.19.

$$\hat{y} = \beta_0 + \beta_1 x \quad [4.19]$$

Where β_0 and β_1 are the least squares estimates, and they can be calculated by the Equations 4.20 and 4.21 respectively.

$$\beta_1 = \frac{S_{xy}}{S_{xx}} \quad [4.20]$$

$$\beta_0 = \mu_y - \beta_1 \mu_x \quad [4.21]$$

$$S_{xx} = \sum (x - \mu_x)^2 \quad [4.22]$$

$$S_{xy} = \sum (x - \mu_x)(y - \mu_y) \quad [4.23]$$

Where S_{xx} is the total variability in x-values, S_{xy} is the total variability in x-values and y-values; and they can be calculated by the Equations 4.22 and 4.23 respectively and μ_x is the mean value of the x-values.

The models listed in Table 4.12 were tested in terms of prediction performance. To compare the prediction performances of the models, mean absolute percent error (MAPE) was used as an error measure and was calculated as follows:

$$\text{MAPE} = \frac{1}{n}\sum_{i=1}^{n}\frac{|\text{actual}_i - \text{predicted}_i|}{|\text{predicted}_i|} \times 100 \qquad [4.24]$$

in which *i* is the project number; actual is the actual cost of the project in TL/m^2; and predicted is the predicted cost of the project in TL/m^2. The procedure used to evaluate prediction performance is based on the cross validation technique and can be summarized in the following steps:

1. The projects of the last two years (2003 and 2004) were selected as the test sample and a new data set was performed. The new data set included data of all of the remaining projects, but not the data of the projects of the last two years which were selected as the test sample.

2. Model parameters for the regression model were calculated with the new data set by regression analysis.

3. The regression model with the new parameters was used to predict the unit cost of the projects which were selected as the test sample.

4. Mean absolute percent error (MAPE) values were calculated according to the Equation 4.16 for the regression models.

The results of the prediction performance test of the models RM1.1 to RM1.8 are presented in Table 4.13.

Table 4.13: Prediction Performance of the models RM1.1 to RM1.8

Regression Model	Independent Variable	MAPE
RM1.1	**BCI**	35,637
RM1.2	**CPI**	37,590
RM1.3	**PPI**	38,453
RM1.4	**CI**	41,248
RM1.5	**$PBPI_1$**	44,173
RM1.6	**$PBPI_2$**	44,392
RM1.7	**$PBPI_3$**	45,570
RM1.8	**$PBPI_4$**	34,333

The prediction performance evaluation, based on cross validation technique, was performed by comparing the calculated MAPE values for each of the models. The best prediction performance belonged to the model RM1.8, with the MAPE value of 34,333 being the lowest among the others.

4.5 Comparison of Indices

In this section the adequacy of the cost indices for the representation of building construction costs for the civil works are compared (See Table 4.14). The linear regression models fitted to the data of 23 projects showed that the BCI and $PBPI_4$ indices gave the best linear fit. The models developed with these cost indices had the best prediction performance among the single variable linear index models studied. Therefore, it could be concluded that the BCI and $PBPI_4$ indices are the most adequate indices among the price indices studied in terms of representation of the variations in building construction costs for the civil works due to inflation.

Table 4.14: Comparison Table for the Models RM1.1 to RM1.8

Regression Model	**Independent Variable**	**Closeness of Fit**		**Prediction Performance**
		P-value	**R^2**	**MAPE**
RM1.1	**BCI**	**0,0000113**	**0,609**	**35,637**
RM1.2	CPI	0,0000157	0,597	37,590
RM1.3	PPI	0,0000190	0,589	38,453
RM1.4	CI	0,0000299	0,572	41,248
RM1.5	$PBPI_1$	0,0000511	0,550	44,173
RM1.6	$PBPI_2$	0,0000537	0,548	44,392
RM1.7	$PBPI_3$	0,0000728	0,535	45,570
RM1.8	**$PBPI_4$**	**0,0000098**	**0,614**	**34,333**

4.6 Prediction of Future Index Values

In the previous section of the study, the BCI and $PBPI_4$ indices were determined as the adequate indices for representing the impact of inflation on building construction costs for civil works. The purpose of this section of the study is to conduct linear and non-linear regression analysis to predict the future values of these indices. The future values of these indices can be used to predict the future cost of building projects. By the use of these predicted values of cost indices, contractors can make more accurate cost estimates at the tender phase of such kind of projects and can prepare more accurate bids which lead to more competitive situations. On the other hand, owners may also benefit from these predicted indices and can use them instead of formulas derived to compensate the contractors against the increasing costs during the execution period of a project. At the same time, owners could improve the feasibility budget with the models developed.

To predict the future values of these indices, it was necessary to find an adequate relationship between the years and the values of these indices. The regression models were built to determine the relation between the years and the indices and were in the following forms:

- For BCI:

$$(BCI)_i = \beta_0 + \beta_1 x_i \qquad [4.25]$$

$$(BCI)_i = \beta_0 + \beta_1 x_i^2 \qquad [4.26]$$

$$(BCI)_i = \beta_0 + \beta_1 x_i^3 \qquad [4.27]$$

$$(BCI)_i = \beta_0 + \beta_1 \log x_i \qquad [4.28]$$

$$(BCI)_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 \qquad [4.29]$$

$$(BCI)_i = \beta_0 + \beta_1 x_i^2 + \beta_2 x_i^3 \qquad [4.30]$$

$$(BCI)_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^3 \qquad [4.31]$$

- For $PBPI_4$:

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i \qquad [4.32]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i^2 \qquad [4.33]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i^3 \qquad [4.34]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 \log x_i \qquad [4.35]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^2 \qquad [4.36]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i^2 + \beta_2 x_i^3 \qquad [4.37]$$

$$(PBPI_4)_i = \beta_0 + \beta_1 x_i + \beta_2 x_i^3 \qquad [4.38]$$

where *i* is the year term from 1994 to 2004; BCI is the value of the building cost index for the corresponding year; $(PBPI_4)_i$ is the value of the produced building price index for the corresponding year; x is the value of the year being 1 for year

1994, 2 for 1995, ….11 for 2004; and β_0, β_1 and β_2 are regression coefficients for each of the models.

With techniques used in previous section, these following equations were tested by regression analysis to determine which function fitted the data best and resulted with a good prediction performance. However, before the regression analysis, the plot of the values of these indices against the years provided a good illustration to portray the relationship between each of these indices and the year term (See Figure 4.10 and Figure 4.11).

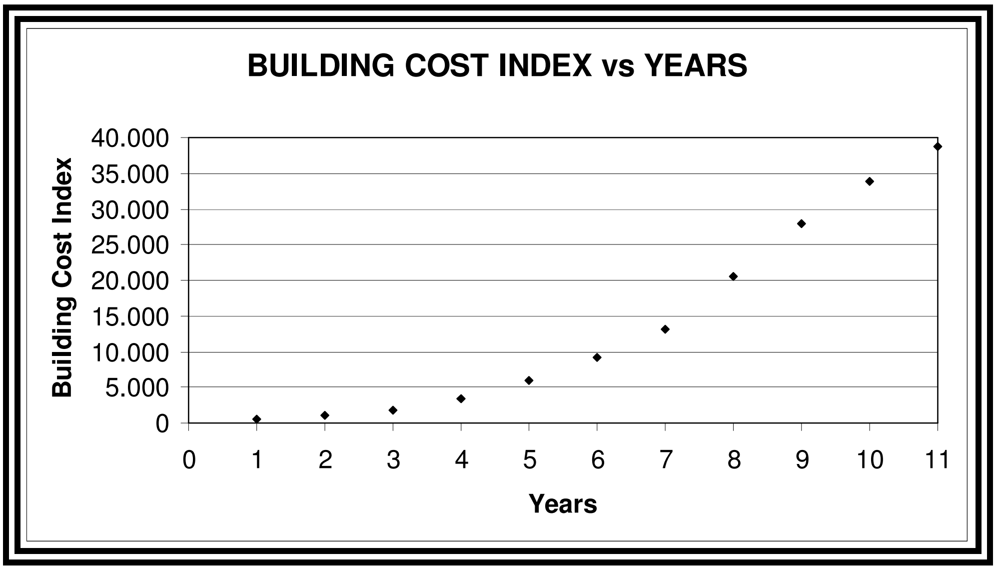

Figure 4.10: Building Cost Index vs. Years

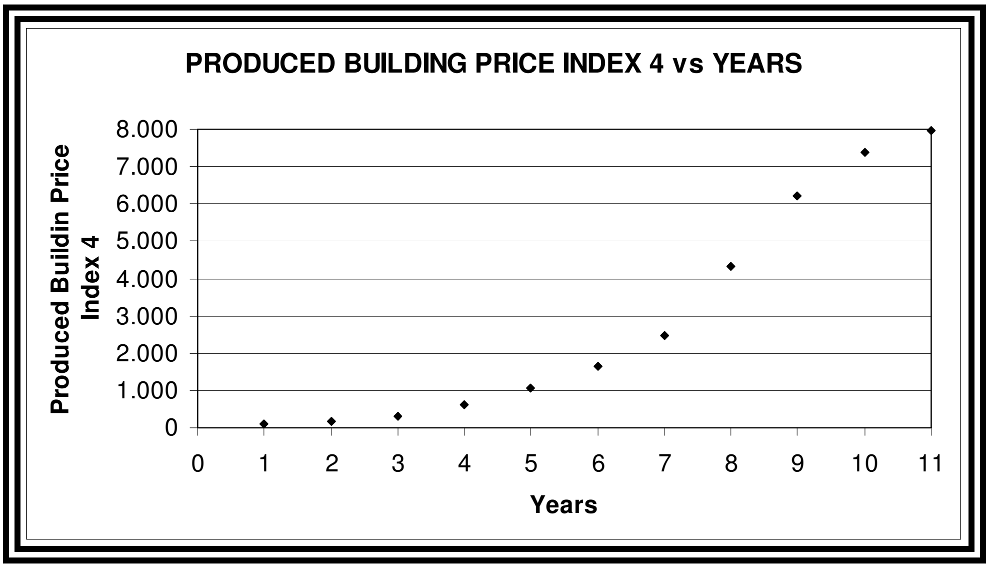

Figure 4.11: Produced Building Price Index 4 vs. Years

These plots gave a clear image of the non-linear relationship existing between both of these indices and the years. Regression analyses were performed for each of the models in the form of the equations numbered from 1 to 14 and the resulting regression statistics were noted.

To determine the closeness of fit, the entire data set was used for regression analysis. The regression statistic R^2 for each of the models is presented in Table 4.15 for BCI and Table 4.16 for $PBPI_4$.

Table 4.15: Closeness of Fit for

Building Cost Index (BCI)

Regression Model with the independent variable *year (x)* in the form of:	R^2
x	0,914
x^2	0,990
Log x	0,677
x^3	0,977
$(x + x^2)$	0,988
$(x^2 + x^3)$	0,980
$(x + x^3)$	0,978

Table 4.16: Closeness of Fit for

Produced Building Price Index 4 ($PBPI_4$)

Regression Model with the independent variable *year (x)* in the form of:	R^2
x	0,895
x^2	0,976
Log x	0,654
x^3	0,964
$(x + x^2)$	0,973
$(x^2 + x^3)$	0,967
$(x + x^3)$	0,965

On the other hand, to evaluate the prediction performance of the above models, again the models were validated by the technique of cross validation¸ and the regression models were driven with the data set excluding the data of the projects of the last two years which were used in the test sample. The values predicted by the models for each year are listed in the Tables 4.17 (for BCI when constant is not 0), 4.18 (for BCI when constant is 0), 4.19 (for $PBPI_4$ when constant is not 0), and 4.20 (for $PBPI_4$ when constant is 0).

The MAPE values of these models are presented in Table 4.21 for BCI and Table 4.22 for $PBPI_4$.

TABLE 4.17: Corresponding Predicted Values of Building Cost Index for each year (Constant ≠ 0)

Year	1 *(1994)*	2 *(1995)*	3 *(1996)*	4 *(1997)*	5 *(1998)*	6 *(1999)*	7 *(2000)*	8 *(2001)*	9 *(2002)*	10 *(2003)*	11 *(2004)*
x	**-3.821**	**-548**	2.724	5.997	9.270	12.542	15.815	19.088	22.361	25.633	28.906
x^2	**-1.084**	**-71**	1.617	3.980	7.019	10.733	15.122	20.187	25.926	32.341	39.432
Log x	**-5.923**	1.480	5.811	8.884	11.267	13.215	14.861	16.287	17.545	18.671	19.689
x^3	875	1.137	1.849	3.236	5.522	8.932	13.692	20.025	28.158	38.314	50.718
$(x + x^2)$	**-1.386**	**-156**	1.688	4.147	7.221	10.909	15.212	20.130	25.663	31.810	38.572
$(x^2 + x^3)$	660	998	1.809	3.297	5.664	9.112	13.845	20.066	27.977	37.782	49.682
$(x + x^3)$	809	1.106	1.848	3.258	5.559	8.973	13.723	20.031	28.121	38.214	50.534

TABLE 4.18: Corresponding Predicted Values of Building Cost Index for each year (Constant = 0)

	Year	1 *(1994)*	2 *(1995)*	3 *(1996)*	4 *(1997)*	5 *(1998)*	6 *(1999)*	7 *(2000)*	8 *(2001)*	9 *(2002)*	10 *(2003)*	11 *(2004)*
	x	2.153	4.305	6.458	8.611	10.763	12.916	15.068	17.221	19.374	21.526	23.679
	x^2	311	1.245	2.801	4.979	7.780	11.203	15.249	19.917	25.207	31.120	37.656
	Log x	0	5.052	8.007	10.103	11.730	13.058	14.182	15.155	16.013	16.781	17.476
	x^3	39	314	1.059	2.509	4.901	8.469	13.449	20.075	28.584	39.210	52.188
	$(x+x^2)$	548	1.643	3.286	5.476	8.214	11.500	15.333	19.714	24.642	30.118	36.142
	(x^2+x^3)	70	419	1.257	2.793	5.237	8.799	13.687	20.112	28.282	38.408	50.698
	$(x+x^3)$	77	386	1.158	2.626	5.020	8.573	13.515	20.080	28.498	39.001	51.822

TABLE 4.19: Corresponding Predicted Values of Produced Building Price Index 4 for each year (Constant ≠ 0)

	Year	1 *(1994)*	2 *(1995)*	3 *(1996)*	4 *(1997)*	5 *(1998)*	6 *(1999)*	7 *(2000)*	8 *(2001)*	9 *(2002)*	10 *(2003)*	11 *(2004)*
	x	**-933**	**-230**	473	1.176	1.879	2.582	3.285	3.988	4.691	5.394	6.096
	x^2	**-376**	**-155**	212	727	1.388	2.197	3.153	4.256	5.505	6.902	8.446
	Log x	**-1.334**	231	1.147	1.797	2.301	2.713	3.061	3.363	3.629	3.867	4.082
	x^3	30	88	245	550	1.054	1.804	2.852	4.247	6.037	8.273	11.004
	$(x + x^2)$	**-439**	**-172**	230	764	1.433	2.235	3.171	4.241	5.444	6.781	8.252
	$(x^2 + x^3)$	**-15**	59	238	565	1.085	1.844	2.885	4.253	5.993	8.149	10.766
	$(x + x^3)$	16	82	245	555	1.062	1.813	2.859	4.247	6.028	8.249	10.961

TABLE 4.20: Corresponding Predicted Values of Produced Building Price Index 4 for each year (Constant = 0)

	Year	1 *(1994)*	2 *(1995)*	3 *(1996)*	4 *(1997)*	5 *(1998)*	6 *(1999)*	7 *(2000)*	8 *(2001)*	9 *(2002)*	10 *(2003)*	11 *(2004)*
	x	445	889	1.334	1.778	2.223	2.668	3.112	3.557	4.002	4.446	4.891
	x^2	65	261	586	1.043	1.629	2.346	3.193	4.170	5.278	6.516	7.885
	Log x	0	1.036	1.642	2.072	2.405	2.678	2.908	3.108	3.284	3.441	3.583
	x^3	8	66	224	531	1.037	1.792	2.846	4.248	6.048	8.297	11.043
	$(x + x^2)$	114	343	687	1.145	1.717	2.404	3.206	4.122	5.152	6.297	7.556
	$(x^2 + x^3)$	15	89	266	590	1.107	1.860	2.893	4.251	5.977	8.117	10.715
	$(x + x^3)$	16	82	245	555	1.062	1.813	2.859	4.247	6.028	8.249	10.961

Table 4.21: Prediction Performance for Building Cost Index (BCI)

Regression Model	MAPE (Constant ≠ 0)	MAPE (Constant = 0)
x	(*) 33,146	60,559
x^2	(*) 3,145	5,909
Log x	(*) 89,188	111,872
x^3	17,571	19,658
$(x + x^2)$	(*) 3,506	9,876
$(x^2 + x^3)$	16,151	17,664
$(x + x^3)$	17,317	19,165

(*) represents the models giving negative predicted values and they will not be taken into account.

Table 4.22: Prediction Performance for Produced Building Price Index 4 ($PBPI_4$)

Regression Model	MAPE (Constant ≠ 0)	MAPE (Constant = 0)
x	(*) 33,621	64,274
x^2	(*) 6,367	7,043
Log x	(*) 92,824	118,175
x^3	19,272	19,527
$(x + x^2)$	(*) 6,213	11,211
$(x^2 + x^3)$	(*) 17,796	17,444
$(x + x^3)$	19,004	19,004

(*) represents the models giving negative predicted values and they will not be taken into account.

The next step was to select the models which resulted in best prediction performance, but with reasonable results (i.e. the models producing negative values shall not be considered). Having examined the Tables 4.21 and 4.22, the best prediction performances belonged to the models derived with the variables x^2 and $(x+x^2)$ when constant was 0 (zero) for both BCI and $PBPI_4$. The models with better prediction performances, in other words with less MAPE values, were ignored due to the negative index values for some year values estimated by the corresponding models (indicated with (*)).

The above mentioned models with the best prediction performances and which produce reasonable index values were examined. In other words, corresponding models were used to predict the future values of BCI and $PBPI_4$ and the results were listed in Table 4.23.

Table 4.23: Predicted values of BCI and $PBPI_4$ for years 2005, 2006 and 2007 and the corresponding Increase Rates (Models derived when constant was 0)

Cost Indices	Model which adequately fitted the data	Actual Value	Predicted Values			Increase Rate		
		Actual (2004)	12 (2005)	13 (2006)	14 (2007)	2004-2005	2005-2006	2006-2007
BCI	x^2	38.797	44.813	52.593	60.996	15,51%	17,36%	15,98%
	$(x+x^2)$		42.713	49.832	57.499	10,09%	11,20%	9,33%
$PBPI_4$	x^2	7.953	9.383	11.013	12.772	17,99%	17,36%	15,98%
	$(x+x^2)$		8.930	10.418	12.021	12,29%	11,03%	9,16%

In order to provide the most reliable prediction for the future cost of a building project, the most reasonable model should be selected to predict the future value of the cost indices. The expected inflation rates provided a basis to evaluate the increase rates of index values between the successive years of 2004-2005, 2005-2006 and 2006-2007. Table 4.24 gives the expected rates of inflation for these years.

Table 4.24: Expected rates of inflation

2004-2005	2005-2006	2006-2007
9,00%	6,10%	5,00%

The models derived by the parameter $(x+x^2)$ for both BCI and $PBPI_4$ (when constant was 0) predicted future values for these indices for the years 2005, 2006 and 2007; which had somehow more reasonable increase rates when compared to the expected inflation rates presented in Table 4.24. Therefore, the predicted values for the years 2005 to 2007 for BCI and $PBPI_4$, achieved as a result of the regression models derived with the variable $(x+x^2)$ when constant was 0, were selected to represent the future costs of building projects and were summarized in Table 4.25.

Table 4.25: Predicted values of BCI and $PBPI_4$ for years 2005, 2006 and 2007

Cost Indices	Actual (2004)	Predicted Values		
		12 (2005)	13 (2006)	14 (2007)
BCI	38.797	42.713	49.832	57.499
$PBPI_4$	7.953	8.930	10.418	12.021

Finally, the actual values of BCI and $PBPI_4$ from 1994 to 2004 and the predicted values for the same indices from 2005 to 2007 are illustrated in Figures 4.12 and 4.13 respectively.

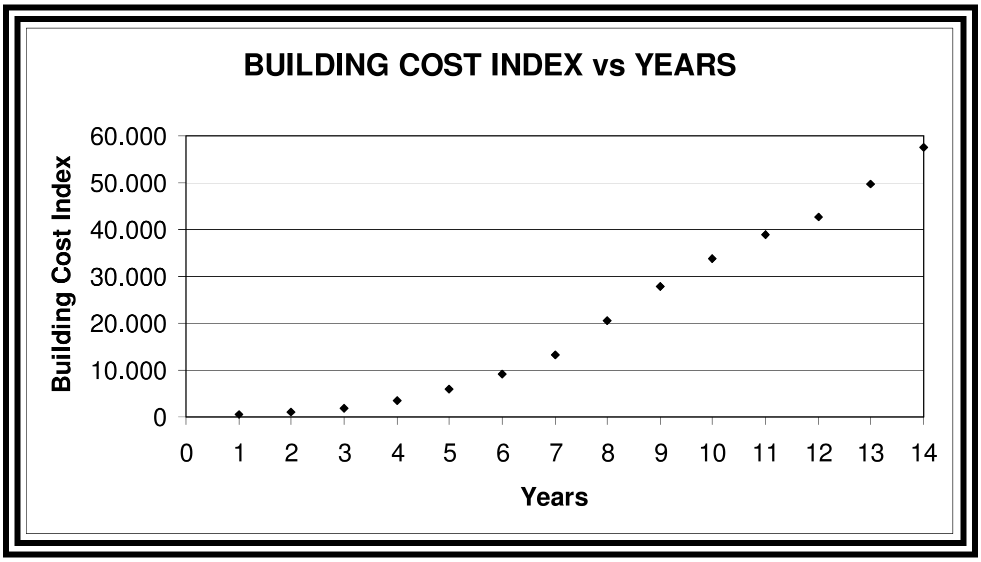

Figure 4.12: Building Cost Index vs. Years including future values

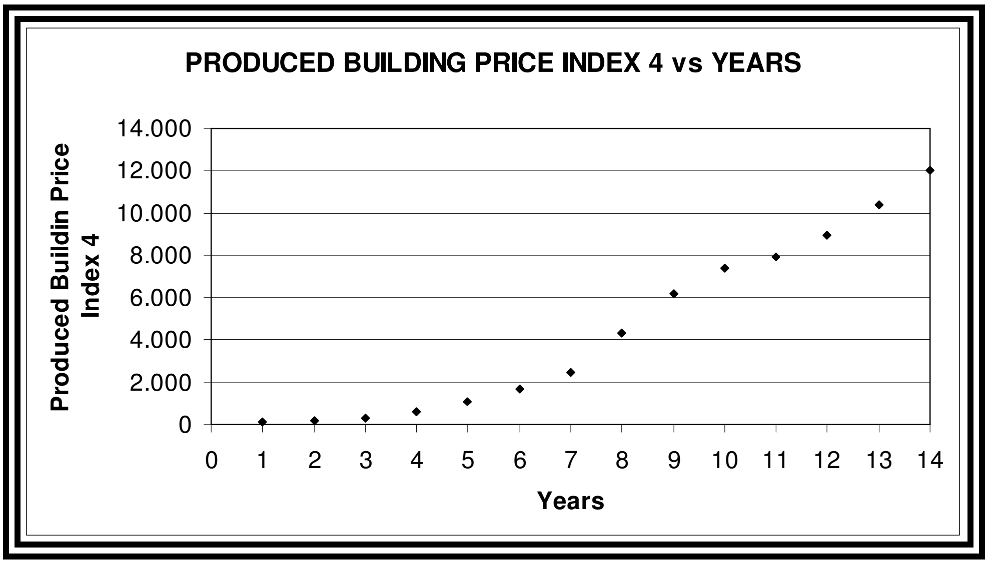

Figure 4.13: Produced Building Price Index 4 vs. Years including future values

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

This research covered the studies performed to compare the existing and newly developed cost indices in terms of their adequacy to escalate the costs of building projects in Turkey. Moreover, the indices that were found to be adequate were analyzed by regression technique, to obtain models to predict the future values of the same indices, which was a way enabling the prediction of the future cost of a building project.

The objectives of the study were outlined in the introductory chapter. The next chapter about the literature review was developed to have a look at the past studies conducted about the concept of price indices and yielded that many studies were performed to develop new cost indices particularly for specific types of construction projects. The newly developed cost indices were based on the past cost data of those projects and were found to be more adequate for the escalation purposes regarding the same type of projects rather than using the existing indices. The techniques followed in the past studies to develop new cost indices were examined and the steps included in the calculation of the same were explained in detail. The third chapter introduced the concept of price index and presented general information about the price indices. The basic variables required for the calculation of price indices were defined and the outline of processes in developing and compiling construction price indices were examined. Moreover, the definitions and components of the existing price indices were studied.

The chapter about the Methodology and Data Analysis covered the steps and detailed explanations of the studies performed to meet the objectives of this research. The data to be analyzed was introduced, and afterwards, the steps for the calculations performed to obtain new cost indices were developed. The developed price indices were compared with the existing ones, and the indices which provided the best linear relationship with the costs of the building projects were selected as the adequate indices to be used to escalate the costs of building projects. Nevertheless, these selected indices were analyzed by the regression technique and the relationship between the years and the values of these indices were investigated. The aim of this step was to achieve a model which would make it possible to predict the future values of the selected indices. Such a step in this study was covered to be able to predict the future cost of a building project, which is needed by the contractors in most cases as described in the introduction to this study.

One of the points that should be mentioned in this study is to clarify whether or not it would be a true method to use the predicted values of the cost indices obtained as a result of the models explaining the relationship between the time and the values of these indices, to estimate the future cost of a building project.

On the other hand, the cost indices developed in this study were based on the data derived from the construction costs of building projects regarding only the civil scope, excluding the costs related with the electrical and mechanical works. Thus, they shall only be used for representation of the cost of the civil scope of building projects. The costs that are related with the electrical and mechanical costs shall be represented by the indices developed by using the past costs of the electro-mechanical scope of the building projects, where the breakdown of the prices are available; or by the existing indices calculated by governmental organizations based on the past price movements in electrical and mechanical work items. However, the best way would certainly be to perform a study similar to this one which would aim to compare the developed and existing price indices in terms of their adequacy.

Furthermore, besides building projects, the cost indices for different types of construction projects, such as industrial plants, highways, dams and power plants, pipelines, etc., can also be developed by using the data about the past costs of such projects and can be used to represent the costs of the same. One of the important requirements to perform such studies is to achieve the price breakdown of the costs of the subject projects, of which data are compiled to investigate the relationship between costs and values of the indices.

This study resulted with the selection of price indices among the existing and developed indices which were found to be adequate to represent the costs of the building projects in Turkey. By using these indices, one shall achieve more accurate results when escalating the cost of a building project. On the other hand, the predicted values of these indices achieved by the derived models will provide more precise results to estimate the future cost of a building project. More accurate estimations shall enable contractors to produce more reliable cash flow forecasts, which is one of the main factors affecting the overall success of a construction project. Furthermore, owners shall also produce better predictions for the budget allocations of their projects, where they can also evaluate several project alternatives with better predictions based on the selected price indices as a result of this study.

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