THE EFFECT OF TIME AND LOCATION ON CHEMICAL PLANT COSTS

MARK BRIAN KNIGHT

Master Of Philosophy

THE UNIVERSITY OF ASTON IN BIRMINGHAM

SEPTEMBER 1986

THE UNIVERSITY OF ASTON IN BIRMINGHAM

THE EFFECT OF TIME AND LOCATION ON CHEMICAL PLANT COSTS

MARK BRIAN KNIGHT   MASTER OF PHILOSOPHY   1986

SUMMARY

A location factor is a means of converting the capital cost of a chemical plant from one country to another. It is used to estimate the capital cost of constructing a new chemical plant in a new location based on the capital cost of an existing chemical plant. A literature survey revealed that there are several methods of calculating location factors, but most of the articles presented no results. Most companies have their own method of deriving location factors but it tends to be costly. Therefore, it was suggested that a method of updating existing location factors would be of more use.

Methods published in the literature are critically appraised and analysed to identify the main influences on location factors. A capital cost model of a chemical plant was developed based on a literature survey of chemical plant cost analyses. A method of updating existing location factors is presented and results obtained using the method are discussed. The method uses a published plant cost index for each country, as this was found to be the only published data which represented the rate at which plant costs have changed in a variety of countries. A list of updated location factors is given. The effect of the exchange rate, and labour productivity on the location factor are also investigated.

KEY WORDS

LOCATION FACTOR
LABOUR PRODUCTIVITY
CAPITAL COST ANALYSIS
PLANT COST INDEX

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr. A. V. Bridgwater, for his invaluable advice and guidance during this research project. I would also like to thank The University Of Aston In Birmingham for providing a research grant which enabled me to carry out this work.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

A location factor is used to obtain an estimate of the investment cost of a new chemical plant at a proposed location (B) based on the investment cost of an existing similar plant of a known investment cost at a base location (A):

$$CB = CA * LF(B:A)$$

where CA - known investment cost at location A

CB - estimate of investment cost of a new plant at location B

LF(B:A) - location factor (ratio of cost at B to the cost at A)

The literature available concerning the methods of calculating location factors and actual values is very limited and often inadequate. Most of the published methods of calculating location factors require an indepth knowledge of any location in terms of inflation rate, costs, labour rates, productivity and an appreciation of special environmental and social factors, as all these may have an influence on the final value.

Location factors tend to be presented very badly in the literature. Ohlrichs [3] makes two very good points in this area:

- Publishing values without indicating in which context they are to be placed reduces the value of these factors.

- It is desirable to standardise the nomenclature, to draw up definitions and to establish procedures.

The objectives of this work are:

(i) Establish a robust definition of a location factor.

(ii) Identify, qualify and quantify the range of influences on a location factor.

(iii) Formulate a method of calculating location factors.

(iv) Determine the value of cost indexes in converting costs from one country to another.

(v) Devise a method of updating location factors.

2 LITERATURE SURVEY

The effect of time and location on chemical plant costs is an area of increasing interest yet sources of information are scarce. Construction of chemical plants is carried out worldwide in an increasingly competitive environment, and with companies looking even more closely at capital expenditure due to the current world economic recession, as accurate an estimate of capital cost as possible is essential for any construction project. The use of historical data is, therefore, suggested with the effect of both time and place on costs taken into account.

It was decided to divide the literature survey into two sections: location factors, and cost indexes. These topics take into account the main areas of interest.

2.1 Location Factors

Location factors are concerned with the relationship between the capital cost of chemical plants constructed in two different locations. This suggested that journals concerned with chemical plants and/or cost estimation could be reasonable sources of information. A general search revealed that the following journals were most likely to be of value:

(a) Chemical Engineering

(b) Cost Engineer

(c) Process Economics International

There seems to have been an increase in awareness of the importance of location factors since 1979, when Bridgwater [1] published a list of factors for 35 countries, and Miller [2] published a method of converting construction costs from one country to another. This is indicated by the increased number of articles published in the literature: Wagialla [4] 1984, Kharbanda [19] 1981 and 1984, Sheridan [33] 1981, and Roberson [14] 1979.

2.1.1 Definition of a Location Factor

Only three definitions of a location factor were found in the literature:

(i) Ohlrichs [3]

"A plant location factor is the ratio of capital investment cost for identical plants, at the same point in time at a different location, relative to a given location and where applicable with a currency relationship valid for that point in time ."

(ii) Bridgwater [1]

"Geographical variations in capital costs are usually quantified by means of a factor that is the ratio of capital costs between two locations. Such a factor may be expressed as a factor related to a base of 1.0 or as an index with a base of 100, at a specified location."

(iii) Wagialla [4]

"The total fixed investment location factor, L(A:B), between a new location (B) and a reference location (A) where the local fixed investment is known, is defined as follows:

$$L(B:A) = \frac{\text{Fixed investment of proposed project at new location,B}}{\text{Fixed investment of reference projects at base location,A}}$$ "

Definition (i) states that identical plants should be compared. It is improbable that identical plants will be constructed at two different locations as there are various factors which influence individual plant design. Another difficulty is that it states that they must have been built at the same point in time. Once again, it is very unlikely that a company will build two identical or similar plants at the same time in different locations. Definition (iii) is said to be dependent on two assumptions:

- The two chemical plants will produce the same product by the same process using similar raw materials.
- The two plants shall have the same actual output.

The second assumption could be important when comparing an industrialised country with a developing country, where the actual on-line time may be lower. Therefore a larger plant will be required to take this factor into account.

The title given to the location factor is also important. In definition (iii) it is called "the total fixed investment location factor", but in definition (i) it is simply called the "plant location factor". No indication is given to what this refers to.

The title should indicate clearly which costs have been included, e.g. does it refer to a battery limit or a greenfield site. It is of little value to call it simply a location factor, as this is meaningless to anyone except the person who generated the figure. Alonso [5] quotes a 'National Price Factor' for twelve countries based on the United States. This is different to a location factor as it is meant to reflect the difference in productivity, transportation and labour skills between two locations. No indication is given on how this Price Factor was derived.

The ideal definition is considered to be that of Ohlrichs, definition (iii), but this is unworkable as explained above. The suggested definition of a location factor is as follows:

"A location factor is the ratio of capital investment cost for plants of similar function relative to a given location. It should be quoted with the appropriate exchange rate and basic information concerning the type of plant, costs, and the year of construction."

'Similar function' refers to plants that have the same actual output, use the same process and raw materials to produce the same product. If necessary, cost indexes should be used to convert the cost of a plant from one year to another. It may also be necessary to adjust the cost to take into account any difference in on-stream times which could affect plant capacity [4].

2.1.2 Plant Cost Analysis

In order to investigate what location factors are and what influences them, it is necessary to understand what the major costs are when building a chemical plant. A literature survey revealed that there is no set way in which a cost analysis of a chemical plant should be presented. The simplest cost breakdown (figures taken from Table 2.1) is:

Direct costs 70%

Indirect costs 30%

This is, however, of very little use as it gives no indication of the major cost components. The first indication of agreement is given by Peters and Timmerhaus [6] who compare costs from three independent sources. This has been reproduced in Table 2.1. On comparing the figures presented, it can be seen that they agree reasonably well.

Table 2.1 Comparison of cost analyses for three chemical plants presented in the literature [6]

COMPONENT	REFERENCE 10	REFERENCE 9	REFERENCE 8
Purchased equipment	23	23	23
Installation	9	10	9
Instrumentation and control	3	3	3
Piping	7	9	9
Electrical	4	2	2
Building	8	6	7
Yard improvements	2	3	5
Service facilities	13	13	11
Land	1	1	1
TOTAL DIRECT COST	70	70	70
Engineering and supervision	9	8	10
Construction expense	10	9	8
Contractor's fee	2	4	3
Contingency	9	9	9
Fixed Capital Investment	100	100	100

Table 2.1 shows that the labour cost is often overlooked as an individual cost component. The analysis presented by Aries and Newton [7] quotes one figure to cover all installation costs, but there is some disageement concerning what should be included in this cost. Peters and Timmerhaus [6], for example, state that structural supports, insulation and paint should be included, but Jelen [11] states that these should be excluded. Allocating which costs should be included appears to be a matter of personal choice. Only Bauman [10] gives a separate labour component as a major cost in the building of a chemical plant.

From cost analyses presented in the literature, it can be seen that the following components should be included in any attempt to formulate a cost model of a chemical plant:

<u>Major Equipment Items</u> [6],[15]

- all equipment listed on a complete flow sheet
- freight charges to site
- taxes, insurance, import duties

<u>Process Materials</u> [6],[10]

- piping and duct work
- electrical equipment
- insulation
- instrumentation
- painting
- concrete foundations

Total Labour [2],[15]

This cost component is not as straight-forward as the others as most cost analyses fail to separate the labour cost component. The component can be broken down into four individual cost factors:

(a) Basic wage

A basic wage is available from statistical sources published by Governments but usually not for construction sites. This information can be used, but care must be taken because it is sometimes quoted as a national basic wage but no account is taken of any local agreements which may have a profound effect on the cost, such as individual union agreements on productivity.

(b) Additional benefits

This is open to considerable variation in time and place. The following costs are usually included: paid leave, bonuses, taxes, insurance and subsidies. Consider, for example, the use of labour on a lump-sum contract. This is usually brought in from a country where labour is readily available, skilled and cheap. The labour force will expect somewhere to live and food to eat which can be expensive in some remote locations. The use of expatriates will also be very expensive as good accommodation is required and return journeys to home will have to be paid for. The additional benefits are therefore dependent on the country in which the plant is being built and the labour force being used.

(c) Cost of Supervision

The cost of supervision must be included in the labour cost. Massa (15) suggests that the ratio of workers to supervisors in the U.S. is 16:1 but may be as low as 6:1 in some foreign countries. This could become very costly if expatriates are used as supervisors for reasons given above.

(d) Labour Productivity

This is the most uncertain factor and is thought to be one of the most important influences on a location factor [2]. There is very little information detailing how productivity can be or is measured in the chemical plant construction industry. This subject is discussed in chapter 5.

<u>Home Office Costs</u> [6],[10],[15]

This should only be the cost of materials and services; where possible, labour costs incurred should be included in the labour cost component. Costs to be included are:

- Engineering drawing
- Drafting
- Purchasing
- Reproduction and communications
- Travel and living

Field Expenses [6],[10],[15]

These include:

- Contractors fee
- Construction equipment, tools and rental
- Taxes and insurance
- Temporary construction and operations
- Any indirect costs of the contractors incurred during the building of the plant.

Other costs such as access roads, telecommunications, and general site facilities (e.g. toilets) also need to be categorised. If a battery limits chemical plant is considered it is reasonable to suggest that yard improvements and land can be neglected. Service facilities are, or can be, considered as factors which influence costs rather than a cost component. The cost of buildings is very difficult to categorise. Roberson [14] does not include the cost of buildings in his conceptualised model of a chemical plant but it is clear from capital cost analyses presented in the literature (see Appendix A) that it should be included. Peters and Timmerhaus [6] state that the buildings cost should comprise of:

Process buildings (platforms, stairs etc.)
Ancillary buildings (administration)
Maintenance shops

2.1.3 Factors That Influence Individual Plant Costs

(a) Climatic conditions

The major effect of the climate is to influence the design of a chemical plant. An example of this is a chemical plant to produce styrene. If it is built in a 'hot' country it is necessary to spend extra capital insulating the product storage area and taking precautions elsewhere to prevent the styrene from polymerising. Cooling requirements are also likely to increase. Cold climates may force the inclusion of heating facilities, and heat recovery equipment may also become important. Utilities may also be affected as requirements may increase or decrease depending on the variation in climatic conditions from the mean. (When comparing costs this will be that of the base case). Conditions such as permafrost increase the cost of laying foundations and also general working costs. Labour efficiency, for example, may also be detrimentally affected. Therefore climatic conditions must be considered when costing a chemical plant for a new location based on a reference location and an existing capital cost.

(b) Topographical features

This area covers the natural geographical features of the location. These may affect such costs as the laying of foundations and site layout. Transportation costs may also be influenced as the geographical features of the land may be difficult to traverse. Remote locations may require improved or new transport roads.

(c) Economic and political climate

A major effect of the economic climate within a country may be (or is likely to be) the protection by the Government of national interests. If the country is in a recession then the Government may require that a percentage of equipment and/or labour must be obtained locally. Unions may also put pressure on the contractors to use a certain number of local people. This could lead to overstaffing in certain areas thus resulting in an increase in costs. In a heathly economic climate, the cost of labour may increase above the rate of inflation, and skilled labour may become in short supply.

(d) Legislation

There are three main areas where Government may influence the cost of a chemical plant:

- Enviromental regulations: these tend to vary from country to country. Industrialised countries tend to set higher standards than those of developing countries. To conform to environmental regulations it may be necessary to spend additional capital ensuring that they are met; the more stringent the regulations the higher the capital expenditure required.

- Health and Safety regulations: Governments impose laws to protect the workforce from injury while at their place of work. These laws will vary from country to country and therefore capital expenditure required to conform to them will also vary.

- Socio-Economic factors: as discussed above, the Government can demand that certain purchases are made locally, but they can also cause problems with such matters as planning permission. They can also aid costs by offering incentives to a company to build a plant in their area. An example of this are tax incentives and grants to induce companies to build in specified areas. These incentives could be very important in deciding where to build a chemical plant.

- Transportation: A rural area has a distinct disadvantage compared to an established industrial area in terms of transportation facilities. Industrial areas usually develop due to the existence of good transport facilities such as motorways, rail network, sea or canals. When constructing a chemical plant in a given country, transportation of the required materials must be considered. Building a plant away from existing systems will result in transport systems having to be constructed at considerable expenditure.

- Actual location: The capital cost of building a chemical plant may not be the first consideration when choosing a location. Factors such as availability of raw materials and sales market may outweigh the importance of capital cost. The proposed location must be suitable for the type of plant being constructed, therefore choice may be limited.

2.1.4 Methods of Calculating Location Factors

2.1.4.1 Introduction

The methods presented in the literature can be classified into two categories:

(i) Theoretical - These are methods that have not been tried out but are possible ways in which to calculate location factors.

(ii) Practical - These are methods that have been shown to be workable.

In some cases, the term 'method' has been loosely applied, for example, the article presents worksheets which illustrate how an actual cost was converted from one country to another.

2.1.4.2 Theoretical Methods

Three theoretical methods have been found in the literature:

(1) Ohlrichs [3]

The definition of a location factor given by Ohlrichs, (see definition (i) Section 2.1.1), states that identical plants should be compared. Ohlrichs states that this is unlikely to occur as very few contractors build identical plants in two different countries. Therefore his proposed method is based on the cost comparison of identical components of chemical plants at different locations, thus improving the probability of finding such data. A modular approach is therefore suggested.

The first step is to group the main influencing factors into four categories:

(i) A1 - Factors of quantitative nature

(ii) A2 - Factors of price level nature

(iii) A3 - Factors of qualitative nature

(iv) A4 - Factors of 'other' natures, which cannot be brought under A1,2,3, such as currency, finance etc.

The factors are related to the following areas, i.e. the major factors involved when building a chemical plant which will have an affect on it:

(a) B1 - The project

(b) B2 - The company

(c) B3 - The country

(d) B4 - The region

(e) B5 - The defined location site

Ohlrichs is aware that there are difficulties in comparing data from different companies. Each company has its own style which influences the way in which a project is handled from start to finish which in turn may also affect costs. Project size and type of plant may also affect costs but no mention is given concerning the possibility of compiling indicators for a variety of plant types and sizes. It is my view that when data is collected it should be accompanied by information about the source. Information such as type of project, process used, dates of construction, breakdown of expenditure during construction, and details concerning any abnormal conditions during the construction of the plant could be very useful when analysing the final cost breakdown. Any information is better than none.

For each of the four categories (A1 to A4), Ohlrichs gives a comprehensive list of 'facts and aspects' which may influence the main factor. Using this approach Ohlrichs suggests that individual indicators can be compiled from factual cost data obtained from interviews and local observations. This would enable any special conditions such as labour or material constraints to be taken into account when determining the location factor for any area. A simple analysis of costs from a previous project may not highlight these conditions. Ohlrichs points out that any indicators will be based on historical data and it is necessary to be aware of any possible cost changes which may occur or already have since the data was obtained. The best method of obtaining information is to carry out a cost survey by visiting the proposed site and talking to companies first hand.

The method presented by Ohlrichs is really a detailed analysis of what factors/influences should be taken into account when calculating a location factor. It would be impossible to quantify all the factors listed as some counteract each other and others cannot be distinguished from one another. No real structure of a method is given by Ohlrichs, there is no mention of how a single location factor can be obtained from the four indicators. It would have been better if Ohlrichs had suggested ways in which the data could be presented in such a form that would illustrate how data could be manipulated to obtain a location factor. The idea is conceptually feasible but difficult in reality. The good points of the article are the definition of a location factor, and the criticism of the way in which location factors are quoted in the literature.

(2) C.Roberson [14]

The method proposed by Roberson is based on the conceptualised model of a chemical plant. The cost is broken down into seven categories:

(i)	Main Equipment	33%
(ii)	Instruments	7%
(iii)	Piping	15%
(iv)	Electrical	4%
(v)	Civil	10%
(vi)	Painting/Insulation	2%
(vii)	Design	29%

This is only a proposed model of a chemical plant and it can be altered to represent any chemical plant. No labour cost component has been included in the cost model. This is surprising because Roberson states that the difference in investment cost from location to location is due to productivity and labour relations, as well as nationality and financial exchange rate. In his model, labour and productivity are either assumed to be unchanged when considering different locations, or no figure could be put to them. To his credit, Roberson states that the measurement of the factors listed above is difficult and sometimes impossible.

Each of the components is then divided into as many subsections as are required and a weighted percentage of the total capital cost is assigned to each. A full list is presented in Table 2.2. For each subsection, a definition is given of the costs which make up the subsection. An example is given below.

Vessels - cost of fabricated vessel in carbon steel delivered FOB site. Total weight 5 tons.

Pumps - Cost of designated electric driven pump, quantity.

Table 2.2 Weighted percentage of parameters of a chemical plant presented by Roberson [14]

ITEM	PERCENTAGE	PARAMETER	WEIGHTING
Main equipment	33	Vessels	20
		Pumps	13
Instruments	7	Flow	1.25
		Temperature	1.25
		Pressure	1.25
		Level	1.25
		Analytical	2.00
Piping	15	Welded C/steel	10
		Screwed C/steel	5
Electrical	4	1.5HP Motor	4
Civil	10	Concrete	7
		Steelwork	3
Painting/ insulation	2	Painting	1
		Insulation	1
Design	30	Design	10
		Drawings	15
		Supervision	5
		TOTAL	101%

Each subsection, although fully covered, can include more parameters, e.g. main equipment items could be altered to include the cost of heat exchangers or any other type of equipment commonly used in a chemical plant. Parameter weightings can also be adjusted to suit a particular type of plant. This may improve the results obtained and will reduce the effect that the one parameter has on the overall value, but it will make the method slightly more time consuming when trying to collect data. By using this model for a number of countries and choosing one as a base, a list of location factors can be compiled. Unfortunately the total of the weighted percentages of the items listed in Table 2.2 adds up to 101% due to a discepency in the allowance for design.

As previously stated, Roberson fails to include the effect of labour and productivity which may have some influence on the location factor. This is the main disadvantage of the approach. The method proposed is very simple as Roberson states that much time and effort can be wasted on inconsequential factors or elements, and in analytical resources. As no results are given it is impossible to say how accurate this method may be, but it would probably be useful as a first estimate when converting costs from one country to another. If it were altered to include labour, it may provide some interesting results to be compared against those obtained using more complex methods. The article does have some value because it defines costs that are incurred when building a chemical plant and then suggests a way in which these costs can be represented by weighted parameters, the costs of which may be more readily available. No details or references are given which may have shown how Roberson arrived at the conceptualised cost model of a chemical plant.

(3) R.V.Massa [15]

The method presented by Massa is much more detailed than any of the methods discussed so far and therefore requires more data to which the user may not have access.

The proposed method calculates a 'Composite Cost Location Factor' based on the U.S. Gulf Coast. The first step in the method is to establish the cost breakdown of a U.S. Gulf Coast erected plant cost. It is assumed that the plant at the new location will have the same percentage cost breakdown. Massa presents a three component cost analysis of a Gulf Coast chemical plant with the weighted percentages of the total capital cost as follows:

(i) Labour Index Factor (33.05%)

The following are the components which make up the Labour Index Factor:

- Basic Wage: actual wages, allowances
- Additional benefits: paid leave, bonuses, pay roll taxes, insurance, subsidies. This is quoted as a percentage of basic wage.
- Supervision ratio (leads to costs)

- Productivity of labour (multiplier for wages and benefits)
- Construction equipment costs. (Usually considered as an indirect expense but in this case it is included in the labour cost component.)

Each individual cost is added directly together to give a final value for both countries. Reducing the value of the base location to 1.0 by dividing both values by the base cost component, enables a simple comparison to be made. It should be made clear that no figures are presented in the article and that the method is illustrated by means of a theoretical worksheet.

(ii) Material and Equipment Index Factor (53.45%)

This has two subdivisions:

(a) Equipment purchases (39.23% of total capital cost)

- Mechanical purchases
- Cranes
- Pipes, valves and fittings
- Instrumentation
- Electrical

Each of the above costs are broken down further, and each cost given a weighted percentage. The above costs also include transportation, handling at docks, import duties and taxes.

(b) Civil Material Purchases (14.22% of total capital cost)

This is subdivided into the following components:

- Structural steel
- Superstructural covering
- Tank steel
- Cement
- Sand
- Gravel
- Lumber

As with equipment purchases, each of the subcomponents is given a weighted percentage. Civil material purchases are separate because they will probably be available locally and therefore many additional costs will be avoided. Using the costs for each of the items listed, a total can be obtained and from that a ratio of costs of the new location to the base location (i.e. base cost = 1.0).

(iii) Indirect and Home Office Cost Index Factor (13.50%)

The two major subdivisions are:

(a) Indirect costs.

- International expenses
- Temporary facilities
- Field staff and expenses
- Equipment rental

(b) Home Office costs

- Engineering design
- Procurement costs

The same procedure is carried out as for the previous components.

The method is very detailed, perhaps a little too much so. The major influences such as labour productivity have been included but the article has one major downfall; most of the tabulated data presented in the article is out of date. An example of this is transport costs. Since 1974 fuel prices have increased substantially thus resulting in an increase in transportation costs considerably above that expected due to general inflation. Therefore presenting 1960's transport costs in a 1983 context without making any attempt to update them is inadequate. No mention is made of the effect that the prevailing exchange rate may have on the results. The method appears feasible but as stated before, no results are presented.

2.1.4.3 <u>Practical Methods</u>

(1) The most recent method presented in the literature is that by Wagialla [4]. It is primarily concerned with the conversion of costs from a developed to a developing country. Wagialla presented a worked example using U.S. Gulf Coast and Saudi Arabia.

The first step is to define the project by specifying the following based on a reliable reference location:

Product quality specifications

The process

Site description

Actual attainable production capacity

Time-base of cost estimate

By defining the project in each case, differences can be easily spotted and account taken in the cost comparison. Wagialla makes it clear that a reference location should be used for which data is available. For this reason the U.S. Gulf Coast is ideal as it is an industrial location with historical data available.

Determination of the importance of the on-stream factor on the reference plant capacity is the next step. This has not been included in any other method. It is important to ensure that the reference plant and the new proposed plant have the same actual product output. If a plant has a lower on-stream factor (the ratio of actual operating days to calendar days per year) it is clear that the plant will have to produce more on those days it is in operation and thus will need to be larger than the existing or reference plant. From the reference capacity and the on-stream factors for both locations a new capacity for the proposed plant can be calculated. Since the data is for the old size it is necessary to use scaling to calculate the capital cost of the proposed capacity from the original capital cost. A scale factor of 0.78 was used and not the universal factor of 0.6 because Wagialla claims it is generally agreed that the old universal factor is no longer acceptable and that different scale factors need to be used for different types of plant.

The next major step is to break down the cost of the reference plant, a 450000 Tonnes/annum ethylene plant built on the Gulf Coast in 1984, into the following components:

Equipment and machinery (delivered to site)	51.39%
Installation	20.39%
Civil works	17.33%
Miscellaneous	4.89%
Engineering	6.00%

Individual location factors are then estimated for each of the five components which are based on field investigations, consultations with industries involved in plant construction, and from experience (intuition). Therefore, any factor is dependent on the person carrying out the investigation. Intuition may be useful to the individual concerned but when considering a logical approach to calculating a location factor, it is not very scientific. A summary of the itemised location factors is presented below.

COST ITEM	ITEMISED LOCATION FACTOR
Plant, equipment and machinery delivered to site	1.584
Installation	1.2
Civil works	1.0
Miscellaneous	1.2
Engineering	4.0

Using the factors given, it is now possible to obtain the cost of the plant at the new location by multiplying the component cost by the individual factor and then adding each component together the values. By dividing the total cost of the new plant by the reference plant cost, an overall location factor can be obtained. A location factor of 1.53 for the Arabian Gulf (Saudi Arabia) relative to the Gulf Coast (U.S.) is derived in the article based on construction items only. Wagialla then describes and quantifies other costs which should be included in the location factor.

Escalation allowance

If the cost escalation is different between the two location, and/or one plant will take longer to build, this will result in additional costs being incurred, e.g. repayment of loans, labour still required, hiring of equipment.

Construction financing

The U.S. interest rate is 12% but when constructing the plant in Saudi Arabia, part of the construction cost is usually invested in short term investments in order to earn some interest. Therefore interest is earned to help reduce costs.

Other cost comparisons included by Wagialla are:

Prefeasibility study

Feasibility study

Site development

Land

Start up

Other capitalised costs (staff training, management contracts etc).

When these costs are included, an overall total fixed investment location factor can be calculated. In the example quoted, the final location factor (Saudi Arabia/U.S.) is 1.378.

The method presented is very detailed and covers most, if not all, costs that may differ between two locations. The method is well described and easy to follow. The only criticism is that it relies heavily on experience. This would involve expenditure travelling to a proposed location and carrying out a detailed analysis, although the data obtained from doing this would be useful in indicating any disadvantages and advantages of local conditions. The term 'installation' is used to cover the cost of labour but it also includes equipment rental which disagrees with other definitions [6],[10]. Labour productivity is also not mentioned. The good feature of the article is that it presents a detailed worked example to illustrate how the method works and the type of results obtained.

(2) Miller [2] presents a "stream-lined" method of converting construction costs from one country to another. The starting point of the method is to break down the capital cost of an existing chemical plant or of an estimate, into four main cost

categories. In this case, a U.S. Gulf Coast chemical plant is used.

Engineering and project management	15%
Direct material	57%
Indirect costs	15%
Direct labour	13%

The second stage is to adjust the cost to a normal or base cost. This means that the effect of any abnormal conditions which may have existed during the construction of the reference plant must be removed. Influences have been previously covered and Miller gives some quantitative information in tabular form on the following:

Travel and living expenses

Climate

Site conditions

Economic climate

Labour productivity

The third step uses correction factors to convert the normalised cost at the known location to the normalised cost at a new location. Correction factors are basically differences in cost which may occur between the two locations. These are well described, qualitatively and quantitively, in the article. Each factor will have some effect on the cost of the chemical plant at the new location. The final step is to readjust the cost at the new location for any abnormal conditions which may be present.

The article presents well documented examples to illustrate how the method works. Most of the influences are taken into account which other methods fail to do and Miller refers specifically to labour productivity as a key to the accuracy of the method, which is said to be in the range of (+/-) 5-20%, but gives no guide to how it should be measured. A good feature of the article is that it presents some results which compare favourably with another source [2] published at about the same time. The values are within (+/-) 5%. The values are shown below, the exchange rate (Ex.rate) is expressed in units of currency per U.S. dollar.

<u>Basis U.S. = 1.0</u>

	U.K	Ex.rate	Canada	Ex.rate	Year
Miller [2]	0.87	0.4961	1.13	1.186	1979
Bridgwater [1]	0.90	0.4807	1.15	1.1581	1979

(3) Nelson [16] presents a method which shows how location factors can be built up. Nelson breaks down the capital costsinto the following main cost components:

Delivered equipment and materials

Labour cost

Contractors cost

Job duration (time taken to do job)

and engineering drafting, design)

Each of the components is broken down into smaller components and are described qualitively and quantitively where possible.

Each cost for the base Gulf Coast plant is given a unit basis factor of 1.0. Then, for two other locations, New Jersey (U.S.) and Finland, unit basis factors are assigned based on the equivalent value in the Gulf Coast, i.e. if equipment cost is the same in both locations, it will be assigned a value of 1.0 or if it costs more in the locations being compared with the Gulf Coast, a value of 1.05 may be appropriate (or 0.9 if vice versa). Multiplying the unit basis factor by the component percentage cost of the installed plant and adding the resultant values together gives a value for each location relative to a Gulf Coast value of 100. By dividing throughout by 100 gives a location factor for each location relative to the U.S.

The method may be useful in obtaining a quick estimate of a location factor but it still relies heavily on experience and/or intuition. No explanation is given as to how the unit basis factors are compiled or why there is such a difference within a country. An example of the differences within a given country is demonstrated by labour productivity:

Gulf Coast (U.S.)	1.00
New Jersey (U.S.)	1.75

A regional difference of 75% is difficult to believe although it may be possible due to the type of experienced labour available in the Gulf Coast region. Nelson calculates two location factors relative to the U.S. Gulf Coast (1.0):

New Jersey (U.S.)	1.269
Finland	1.02

The figure for New Jersey (U.S.) suggests that there is a significant variation in location factors within the U.S.

Other information given in the article includes tabulated data for equipment costs and material prices in six countries, transportation costs as a percentage of equipment or material costs, wages salaries and benefits for 8 states in the U.S., comparison of the cost of keeping supervisors on foreign jobs, and comparison of the cost of engineering relative to the U.S. Gulf Coast for 5 areas.

(4) Bridgwater [1] presents an empirical method for calculating a parity corrected location factor based on the 'Process Economics International' plant cost index for two countries, U.S. and U.K., a datum location factor of 1.10 in 1979, and an averaged exchange rate. This empirical method is dependent on maintaining the accuracy of the cost index with respect to the rate at which the capital cost of a chemical plant is changing with time, and the accuracy of the datum value of the location factor. The article also contains a list of 35 location factors for a variety countries relative to the U.S. and the U.K.

(5) Other approaches: All methods covered so far have been presented as the main body of the article. Two other articles [17],[18], contain worked examples to illustrate how costs can be converted from one country to another.

The conversion worksheet, contained in the article presented by Wallace [17], illustrates how costs are converted from U.S. Gulf Coast to Saudi Arabia. The method utilises a detailed cost analysis of a chemical plant which has been broken down into five components. For each of the five main components, conversion factors relative to the U.S. are given which can be used to obtain the cost in Saudi Arabia:

Engineering	1.14
Direct materials	1.23
Construction indirects	1.43
Construction directs	0.37
Construction subcontracts (buildings etc.)	1.36

The article presents tabulated information for craft efficienies (productivity), wage rate compensations, and equipment rentals for the U.S. and Saudi Arabia. Wallace explains which costs are different and why, which is very useful for background information.

The second of these methods is presented by Gallagher [18]. As in the previous method, the cost of a chemical plant (in this case an ethylene plant) in the U.S. Gulf Coast is broken down into its major cost components:

Equipment	43.75%
Materials	19.27%
Labour	11.72%

Indirect	21.64%
Buildings	3.98%

For each cost component a factor is quoted which represents the ratio of the cost in France 1969 to that in U.S. 1963. Using these factors, the cost of building an ethylene plant in France 1969 can be calculated. This approach is unusual as costs are normally converted at the same point in time. i.e. 1969 U.S. costs converted to 1969 French costs. The article is very interesting as it contains some useful information. The way in which the factors have been calculated is well presented although not all are shown. Those that have been described are:

Labour

Construction field expense

Home office costs

2.1.5 Published values

Only two articles have been found in the literature that present a reasonable list of location factors. In 1979 Bridgwater [1] published the most comprehensive list of location factors to date; factors are given for 34 countries worldwide with the U.S. and the U.K. as bases. The factors represent what Bridgwater thought they were, based on information supplied by others and extrapolation to analogous locations. The response from interested parties apparently confirmed that the published values were reasonable [20].

The second list, first published by Kharbanda [19c] in 1977, presents factors for 18 countries. The same list was also presented in 1981 [19b] and again in 1984 [19a]. The list is a collection of location factors published by various authors in the period 1969-1970, yet in the most recent article published in 1979 [19a], Kharbanda claims that it is the 'latest view' but the values published by Bridgwater in 1979 were not included in the article. This suggests that Kharbanda put in very little effort when compiling the article, nor did he apparently understand the complexity of this topic. Cran [21] presents location index values for 14 countries based on the U.S. His method of obtaining these values must be questioned as Cran simply took the U.S. plant cost index as the base and divided throughout the plant cost indexes to reduce the U.S. to a base value of 100. This should not be called a location index as it is merely the plant cost index relative to the U.S..

Most sources quote location factors for individual countries with the U.S. as the reference location but there are some published values which indicate that a location factor changes within a country. Table 2.3 contains data from various sources which illustrates this point. Ohlrichs [3] also states that there will be regional cost differences within a country, especially if large such as the U.S. or Australia.

Location factors presented in the literature have been collected and are listed later in Table 2.4 . Some values are not strictly location factors, an example of this is the values presented by Alonso [5] which have been previously described. On comparing the values in Table 2.4 it can be seen that agreement between the data seems to be dependent on the type of country, that is to say, major European countries show good agreement while developing countries show a much wider variance in values. This should be expected as it is only recently that developing countries have become of interest when deciding where to build a new chemical plant. Some basic background information has been provided [23] which qualitatively describes the relationship between a developed and a developing country in terms of equipment, labour, and construction costs.

Table 2.3 Location factors variation within in a country

LOCATION	FACTOR
1946 Chicago = 1.00 [22]	
Boston	1.015
New York	1.055
Philidelphia	0.992
Detroit	0.984
St. Louis	1.020
Kansas City	1.007
Dallas	0.971
Los Angeles	1.109
1958 Midwest = 1.00 [13]	
East Coast	1.00-1.10
Gulf Coast	0.90-1.10
West Coast	1.05-1.15
1973 Gulf Coast (U.S.) = 1.00 [23]	
Louisiana	1.06 (0.96-1.51)
East Coast	1.22 (1.10-1.27)
California	1.08 (0.98-1.18)
Great Lakes	1.09 (1.02-1.10)
Oklahoma,Texas	n/a (0.93-0.95)
Wyoming,Montana	n/a (0.91-1.03)

It must also be appreciated that the location factors may not agree well with each other because of the way in which they were derived. Special or unusual conditions may have affected costs. Therefore, one contractor may say the location factor, for a given country relative to the U.S., is 1.8 and another may say it is 0.9, and they may both be right for their specific project.

Location factors are usually presented in the literature as just a number which is supposed to represent the ratio of capital costs for a similar chemical plant in two locations. A number carries very little information if quoted by itself, e.g.

Location factor U.K./U.S. = 1.10

The exchange rate between two countries can change quite dramatically in a short period of time. This would result in a change of costs in one country relative to the other. Therefore, the location factor would change. The effect of a changing exchange rate on a location factor is discussed in chapter 6. The more information that is presented with the location factor, the more useful and meaningful it becomes.

Table 2.4 <u>Collection of location factors published in the literature</u>

YEAR	1961	1962	1962	1962	1963	1969	1969
REFERENCE	[24]	[25]	[26]	[27]	[28]	[29]	[18]
COUNTRY							
Algeria							
Argentina							
Australia				1.00			
Austria							
Belgium	0.87				0.95	0.94	
Brazil			0.96	1.05			
Canada			1.00	0.98			
C. Africa							
C. America							
China (imp, ind)							
Denmark							
E. Africa							
Eire							
Finland					0.95		
France	0.82			1.00	1.05	0.91	0.86
Greece							
Holland	0.82				1.00	0.92	
India (imp, ind)			0.95				
Italy	0.82		0.90	0.90	0.85	0.86	
Iran							
Japan		1.02		0.92	0.83		
Libya							
Malaysia							
Mexico			1.03	1.00			
Newfoundland							
New Zealand							
N. Africa							
Norway					0.95		
Peru							
Portugal							
Saudi Arabia							
S. America N							
S. America S							
Spain	0.77						
Singapore							
Sweden	0.98				0.95		
Switzerland							
Turkey							
U.K.	1.00		0.85	0.85	0.95	0.91	
Venezuela							
W. Africa							
W. Germany	0.88	0.86		0.84	0.90	0.88	
Yugoslavia							

Table 2.4 continued.

YEAR	1970	1971	1972	1973	1973	1973	1975
REFERENCE	[30]	[5]	[12]	[31]	[23]	[16]	[32]
COUNTRY							
Algeria				1.06			
Argentina					1.01		
Australia	1.05	1.20	0.90		0.95		
Austria							
Belgium		0.94		0.95			
Brazil	1.10				0.95		
Canada			0.98		1.06		
C. Africa							
C. America							
China (imp, ind)							
Denmark							
E. Africa							
Eire							
Finland						1.02	
France	0.98	0.91	0.94	0.95	0.90		
Greece							
Holland		0.92					
India (imp, ind)		1.35		1.17			
Italy		0.86	0.89	0.90	0.84		
Iran				1.10			
Japan	0.95	0.83	0.82		0.75		
Libya							
Malaysia							
Mexico				1.00			
Newfoundland							
New Zealand							
Middle East							
N. Africa							
Norway							
Peru	1.04						
Portugal							
Saudi Arabia							
South Africa							
S. America N							
S. America S							
Spain		1.00					
Singapore					0.79		
Sweden		1.09			1.03		
Switzerland							
Turkey				1.10			
U.K.	1.03	0.91	0.90	0.90			
Venezuela					1.02		0.95
W. Africa							
W. Germany	0.95	0.88	0.88	0.95		0.88	
Yugoslavia							

Table 2.4 continued

YEAR	1976	1979	1979	1981	1983	1984
REFERENCE	[17]	[2]	[1]	[33]	[34]	[4]
COUNTRY						
Algeria						
Argentina						
Australia			1.30		0.89	
Austria			1.00			
Belgium			1.00		0.92	
Brazil						
Canada		1.13	1.15		0.92	
C. Africa			1.40			
C. America			1.00			
China imp.			1.10			
China ind.			0.55			
Denmark			1.00		0.80	
E. Africa			1.15			
Eire			0.80			
Finland			1.20			
France			0.95		0.82	
Greece			0.90			
Holland			1.10		0.82	
India imp.			1.80			
ind.			0.65			
Italy			0.90		0.78	
Iran						
Japan			0.90		0.73	
Libya			2.40			
Malaysia			0.80			
Mexico						
Newfoundland			1.20			
New Zealand			1.30			
Middle East			1.70			
N. Africa imp.			1.30			
ind.			0.90			
Norway			1.10		1.10	
Peru						
Portugal			0.75			
Saudi Arabia	1.66					1.38
S. Africa			1.10			
S. America N			1.15			
S. America S			1.40			
Spain imp.			1.20			
ind.			0.75			
Singapore						
Sweden			1.10		0.99	
Switzerland			1.10			
Turkey			0.72			
U.K.		0.87	0.90		0.86	
Venezuela						
W. Africa			1.15			
W. Germany			1.00		0.88	
Yugoslavia			0.90			

Abbreviations used in Table 2.4

C	=	Central
E	=	East
imp	=	Imported material
ind	=	Indigenous material
N	=	North
S	=	South
W	=	West

Table 2.5 presents some recently quoted location factors [20]. The Kuwait location factor of 36% above equivalent U.S. costs is understood to be attributable to the following in approximately equal proportions:

- High ambient temperature
- Transport cost of freightable equipment
- Higher supervisory costs

Table 2.5 Recent Location factors [20]

Basis U.S. Gulf Coast.

YEAR	COUNTRY	LOCATION FACTOR
1983	China	0.90
1978	Kuwait	1.36
1978	Saudi Arabia	1.70
1985	Saudi Arabia	2.00

2.2 Cost Indexes

2.2.1 Introduction

Costs tend to change with time for various reasons which include inflation and increased production costs, of which the former is the most obvious and widely quoted. Therefore it is necessary to be able to represent the rate at which these costs change. This is achieved using a cost index which 'represents the combined but unequal influences of commodities whose prices are changing' [35]. A cost index can be used to represent many factors, but the indexes of interest are those which show how costs in the chemical plant construction industry are changing. The construction of a simple index can be illustrated as follows:

Plant X consists of 30% labour and 70% materials

Cost index for X, $I_x = 0.30L + 0.70M$

where L = Labour cost index

M = Material cost index

In general:

$$I_x = W_1 I_1 + W_2 I_2 + \dots\dots\dots\dots\dots\dots W_n I_n$$

where $W_1 + W_2 + \dots\dots W_n = 1.0$

W_i = Weighted fraction of total index

I_i = Component cost index

A cost index is mainly used to compare the cost of a "commodity", i.e. a chemical plant, from one time to another. If X costs C_1 in year A with a cost index value of I_1, then the cost of commodity X in any year, C_2, can be found as follows:

$$\frac{C_2}{C_1} = \frac{I_2}{I_1} \qquad \text{.........(i)}$$

$$C_2 = C_1 * \frac{I_2}{I_1} \qquad \text{.........(ii)}$$

The left hand side of equation (i) represents the rate at which the cost of X has changed. This can also be represented by the ratio of the cost index values for the given time periods. Commodity X can range from a single piece of equipment to a complete chemical plant, the method is the same.

2.2.2 Published Cost Indexes

There are a variety of cost indexes published in the literature which are important to the chemical industry.

(i) Chemical Engineering Index

In 1963 Arnold and Chilton [36] presented an article in which they described how the Chemical Engineering Index was comprised. The main components of a chemical plant in the U.S. according to the index, were:

Equipment, machinery and supports	61%
Erection and installation labour	22%
Buildings, material and labour	7%
Engineering and supervision manpower	10%

The main component, equipment machinery and supports, is subdivided into seven sections, the largest being fabricated equipment (37% of total equipment cost).

In every issue of 'Chemical Engineering', an overall index, component indexes and subcomponent indexes are published. By using the information supplied, it is possible to change the overall weightings of the components and formulate a new index to suit a particular type of plant.

Over the years, the actual percentage of each component has changed as shown in Table 2.6. These figures were obtained by calculating the percentage that each component index actually contributes to the overall index. The figures in Table 2.6 disagree with those given above because the component indexes which are used to calculate the main index have increased at different rates.

Table 2.6 Change in actual weighted percentage of each component of the Chemical Engineering Index with time

COMPONENT	PERCENTAGE		
	1963	1971	1985
Equipment machinery and supports	58.2	60.1	65.1
Erection and installation labour	23.8	24.3	18.0
Buildings, material and labour	7.5	7.2	6.5
Engineering and supervision manpower	10.5	8.4	10.4

Since the index was first put together, there have been two changes in the way in which the index is compiled. These came into effect in January 1982:

- reduction of the number of components from 110 to 66 with the replacement of many components with more suitable ones.
- reduction of the productivity factor from 2.5 to 1.75

The changes were made in an attempt to track process plant construction cost trends more accurately. Many aspects have changed since the index was first created with more representative sources of information becoming available. An example is the replacement of the salary data from the Engineering Manpower Service and National Society of Professional Engineers, which is published every two years, by annual data published by the U.S. Bureau of Labour Statistics occupational classifications.

The productivity factor, which should really be termed a technological productivity factor, is based on advances in working tools and techniques. When first created, the factor of 2.50 was considered correct based on available information. Since 1969,productivity changes due to technology has slowed down according to the Chemical Engineering Index thus resulting in the factor being decreased to 1.75.

The changes in the productivity factor and the number components used, resulted in a discontinuity in the cost index. Changing the productivity factor from 2.5 to 1.75 caused the index to change from 306.7 to 310.5. The change in the number of components resulted in a minor change of 0.1 in the value of the index [81].

(ii) Marshall and Stevens equipment cost index

This index is also published in every issue of 'Chemical Engineering'. Stevens describes the individual indexes in an article published in 1947 [37]. The indexes are based upon detailed equipment cost assessment and not periodically reported equipment costs. The following components are used in obtaining the individual indexes:

Process or operating machinery

Power equipment

Installation labour

Maintenance equipment

Administrative equipment

Using these given components, indexes are calculated for 47 process industries. The following component indexes are published in 'Chemical Engineering':

Average overall cost index

8 process industries

4 related industries

The average overall cost index is derived from the eight process industries cost indexes as follows:

Cement	2%
Chemicals	48%
Clay products	2%
Glass	3%
Paint	5%
paper	10%
Petroleum	22%
Rubber	8%

(iii) <u>Process Engineering</u>

The derivation of the Process Engineering cost indexes is described by Cran [38]. The index is based on five components:

Mechanical Engineering

Electrical and instrument

Civil

Site costs

Overheads

Each of the five components are divided into subcomponents, usually three, and an index available from Government sources is assigned to each. The weightings of each subcomponent are then given. An example taken from the article is given below:

Electrical and Instrumentation, I_e

$$I_e = uI_4 + vI_5 + wI_3$$

I_4 = Department of Trade and Industry Wholesale Price Index Number for Electrical Engineering

I_5 = Average of the Department of Employment Index Numbers for average earnings in electrical engineering

I_3 = Department of Employment Index of Wages and Prices for Professional Services and Public Administration

Based on the 1968 Census of Production Figures:

$u = 0.6$

$v = 0.2$

$w = 0.2$

Using two sets of average cost analyses abtained from surveys carried out by Boyd and Eady [35], Arnold [9], and the breakdown of costs suggested by NEDO [39], the derived component weightings are as follows:

Mechanical	0.37
Electrical	0.08
Civil	0.10

Site cost	0.19
Overheads	0.26

A review of the five components of the index reveals that civil and electrical costs have increased at the greatest rate.

(iv) Process Economics International Plant Cost Index

Plant cost indexes are published for 32 countries, which is very useful as no other journal does this. All the cost indexes discussed so far have been multicomponent, that is to say they are comprised of more than two cost components, but the Process Economics International cost index is based on two components only:

Basic steel	30%
Earnings	70%

Cran [40] presents a mathematical derivation of a two component cost index based on the breakdown of costs for a chemical plant, and compares this to multicomponent indexes. Very good agreement is obtained, typically within (+/-) 5%. A two component index is a simple but useful cost index.

(v) Nelson Refinery Inflation Index

The base year of the index is 1946, but it was first published in 1949. The percentage weightings of each component have changed over the years as shown in Table 2.7. The labour component, 60% overall, is still obtained from Engineering News

Record. The other required information is obtained from the U.S. Bureau of Labour Statistics.

Table 2.7 <u>Variation of component percentage weightings of the Nelson Refinery Inflation Index with time</u>

COMPONENT	PERCENTAGE		
	1949	1956	1967
Iron and steel	24	20	20
Building materials	8	8	8
Misc. Equipment	8	12	12
Skilled labour	30	30	39
Common labour	30	30	21

(vi) <u>Engineering News Record</u>

The journal, Engineering News Record, provides very useful information which is used in other plant cost indexes. Two cost indexes are published in this journal.

<u>Building Cost Index</u>:

Skilled Labour	56%
Structural Steel	26%
Lumber 2 x 4's	15%
Portland cement	3%

Construction cost index:

Common Labour	74%
Structural Steel	15%
Lumber 2 x 4's	9%
Portland Cement	2%

These indexes have been mentioned because they are often quoted in other journals, Oil and Gas journal for example. The Engineering News Record indexes are not process plant cost indexes and therefore should not be used as such.

2.2.3 Conclusion

As has been shown, cost indexes can be separated into two categories:

- multicomponent
- two component

Two component cost indexes require less data than muticomponent cost indexes but they may lack accuracy due to the limited way in which the index can effectively model how individual plant costs vary. It is therefore necessary to compare the available indexes in qualitative terms. Chapter 4 includes a graphical comparison of cost indexes for the United States and the United Kingdom.

3 MATHEMATICAL PRESENTATION OF A METHOD OF UPDATING LOCATION FACTORS

Most contractors already have their own location factors, therefore it was suggested that a method of updating location factors using published data would be of more use than a method of calculating new factors. [79]

A method of calculating a location factor, in simple terms, is that stated in definition (iii) (see section 2.1):

$$LF_t = \frac{C(B)_t}{C(A)_t} * ER_t \qquad ....(3.1)$$

Where LF - Location factor

C(A) - Capital cost of plant at reference location, A

C(B) - Capital cost of plant at new location, B

ER - Exchange rate (A/B)

Subscript t - A historical point in time referred to as "Then" (existing data)

A new location factor could be calculated in the same way:

$$LF_n = \frac{C(B)_n}{C(A)_n} * ER_n \qquad ....(3.2)$$

Where subscipt n represents data for the plant at a different time n "new" or "now".

Dividing (3.2) by (3.1):

$$\frac{LF_n}{LF_t} = \frac{C(B)_n}{C(A)_n} * \frac{C(A)_t}{C(B)_t} * \frac{ER_n}{ER_t} \qquad ....(3.3)$$

Rearranging:

$$LF_n = LF_t * \frac{C(B)_n}{C(B)_t} * \frac{C(A)_t}{C(A)_n} * \frac{ER_n}{ER_t} \qquad ....(3.4)$$

In order to use this relationship for deriving a new location factor, it is necessary to know the capital costs of the chemical plants. As these are generally not available, the ratio of capital costs is approximated by the ratio of the respective chemical plant cost indexes, which should represent the rate at which the cost of a chemical plant has changed, i.e.

$$\frac{C(A)_t}{C(A)_n} = \frac{CI(A)_t}{CI(A)_n}$$

Where CI = Chemical plant cost index

Substituting into equation (4):

$$LF_n = LF_t * \frac{CI(B)_n}{CI(B)_t} * \frac{CI(A)_t}{CI(A)_n} * \frac{ER_n}{ER_t} \qquad ....(3.5)$$

Using readily available plant cost indexes, it is now possible to update an existing location factor. In deriving equation (3.5) it has been assumed that the influences which may have affected the value of the location factor that is being updated, have not changed with respect to the new plant.

The following is an illustration of how equation (3.5) can be used to update an existing location factor:

A chemical plant cost \$11M to build in the U.S. in 1979. The equivalent plant cost 5M pounds sterling to build in the U.K. The exchange rate was 0.5 pounds/\$. Therefore,

Location factor (1979) = 11/5 * 0.5 (from equation 3.1)

Location factor in 1979 was 1.1 (U.S./U.K.).

Updating this value to 1984 using equation (3.5) and the following data:

1979 U.S. cost index 132
U.K. cost index 173
Location factor 1.1
Exchange rate 0.5 pounds/\$

1984 U.S. cost index 187
U.K. cost index 255
Exchange rate 0.727 pounds/\$

Location factor (1984) =

$$1.1 * (173/255) * (187/132) * (0.727/0.5)$$

Location factor in 1984 = 1.537 (U.S./U.K.)

Using this value, a new plant cost for a new location in the U.K. can be calculated based on an existing capital cost in the U.S.

Equation (3.5) is a simple means of updating a location factor using readily available data. It could be improved by replacing the single plant cost index with a new cost model of a chemical plant derived from cost analyses published in the literature, which uses a cost index for each individual cost component. When using equation (3.5) care must be taken to ensure that the exchange rate used gives a dimensionless location factor.

4 COMPARISON OF COST INDEXES

In order to compare the cost indexes it is necessary to plot the indexes for U.S. and U.K. against time.

4.1 U.S. cost indexes

Figure 4.1 shows a plot of the following U.S. cost indexes against time:

- Process Economics International
- Chemical Engineering
- Marshall and Stevens
- Engineering News Record Construction Index

The data has been reduced to a common basis of 100 in the first quarter of 1975 and is listed in Appendix E. Figure 4.1 indicatesthat since 1975, the Engineering News Record Index has been generally higher than the other three indexes. Considering only the process plant cost indexes then the Process Economics International index presents the highest values. It must also be noted that the indexes are within 10% of each other for any particular month.

4.2 U.K. cost indexes

Figure 4.2 shows a plot of the following U.K. published cost indexes against time:

- Process Economics International

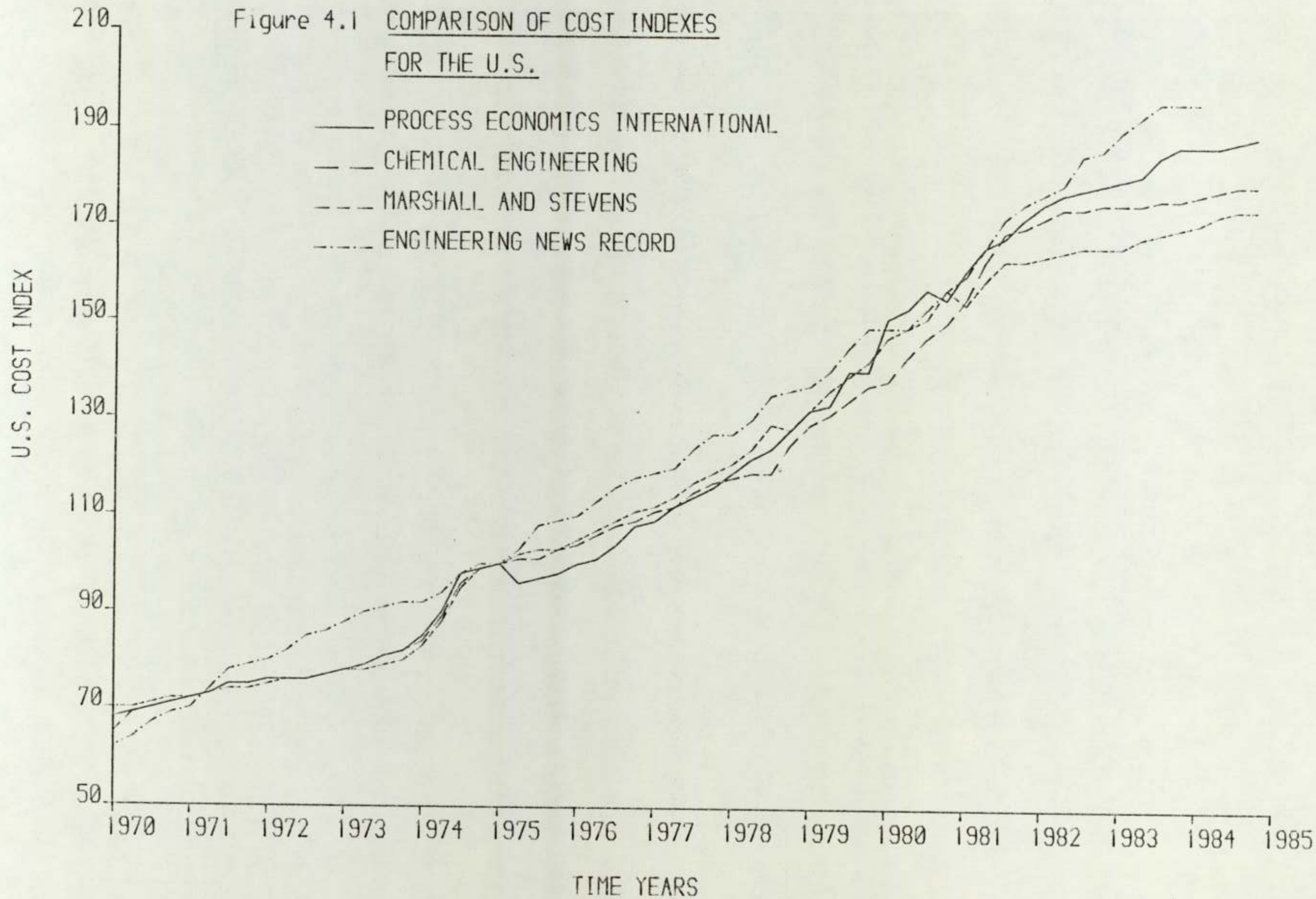

Figure 4.1 COMPARISON OF COST INDEXES FOR THE U.S.

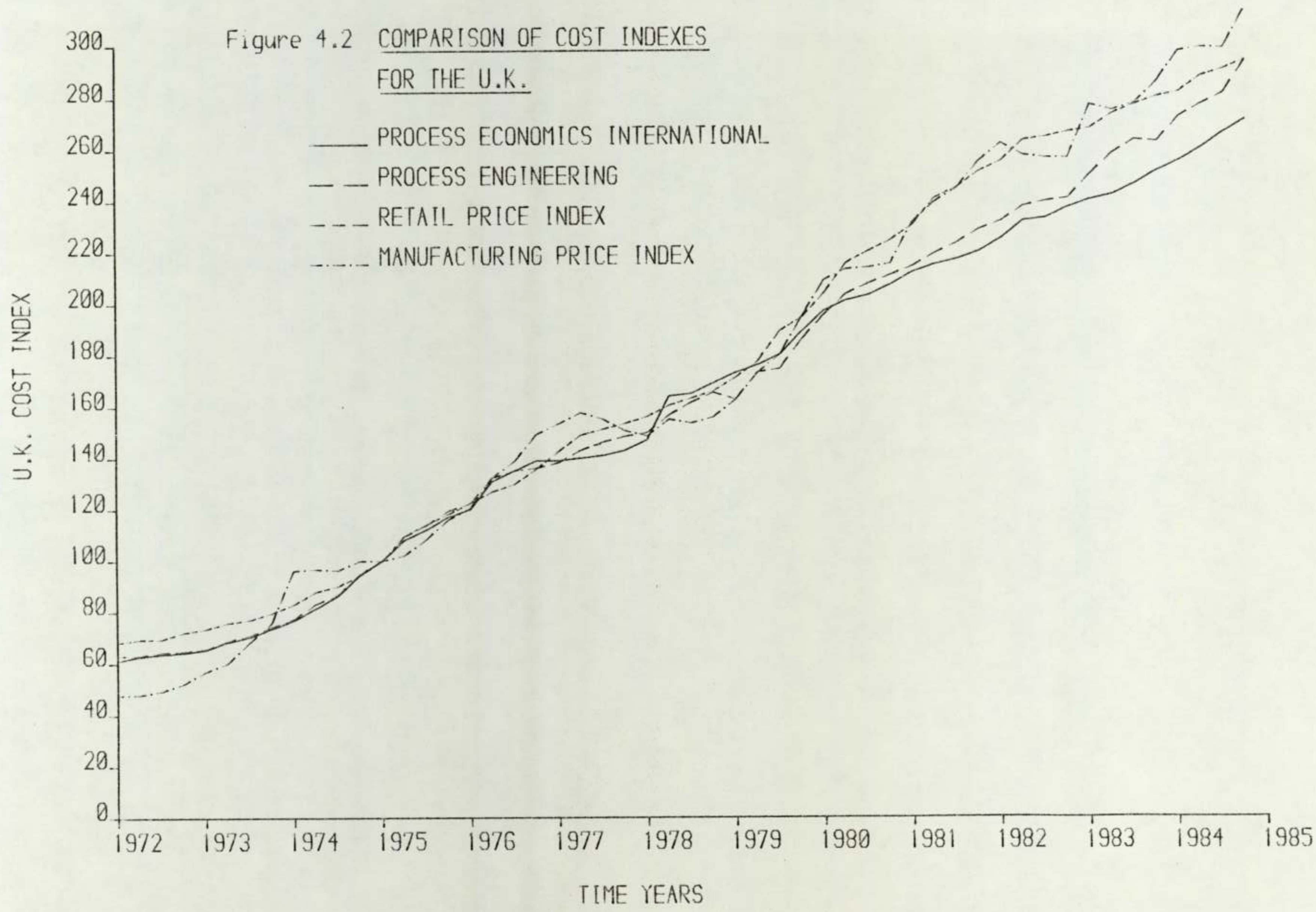

Figure 4.2 COMPARISON OF COST INDEXES FOR THE U.K.

- Process Engineering
- Retail Price Index
- Manufacturing Price Index

Figure 4.2 shows that up to 1980, the indexes were very similar, but since then they have begun to diverge. Process Economics International index has a lower value than any of the others, with Process Engineering index having the highest for any given month.

Table 4.1 Factors which effect the performance of cost indexes [42]

FACTOR	% increase 1970-1980 above inflation
Labour productivity	10 to 20
Environmental legislation	5 to 10
Health and safety regulations	5 to 10
Contract price exploitation	5 to 10
Energy costs	10 to 20
Learning effects	-10 to 0
Technological changes	0 to 15
Commercial forces	-5 to 15

Since 1973, it is said that published plant cost indexes have not reflected the increases in actual costs [42]. In 1976/7 this discrepancy was reported to be between 10 and 30%, and up to 50-60% in 1980. This clearly suggests that plant costs are escalating faster than inflation. Table 4.1 lists some of the reasons for the lower expected rate of increase in cost indexes and also the effect that each factor has had on the performance of the cost indexes in quantitative terms [42]. To make up for the inadequacies of published plant cost indexes, Bridgwater and Bossom suggested a new three component cost index based on essential raw materials and labour indexes published in the literature as follows:

$$I = aI_{LABOUR} + bI_{OIL} + cI_{IRON\ ORE}$$

This was then reduced to a two component index:

$$I = aI_{LABOUR} + bI_{OIL}$$

Where I_{LABOUR} = Index of the hourly labour rate in the U.K. construction industry.

I_{OIL} = Index of imported price of crude oil

Two different sets of values of a and b were found using alternative methods:

a	0.175	0.18
b	0.825	0.82

Using reported discrepancies in the value of plant cost indexes as a guide, it is suggested that the proposed new index adequately represents the way in which plant costs had changed up to 1980. But by using the cost of crude oil as one component, the index would be subject to outside influences such as the OPEC countries,who attempt to control the prices. In 1973/4 oil prices rose dramatically which most plant cost indexes did not show. Using the two components, an increase in oil prices of 100% could result in the plant cost index rising quite dramatically, depending on the relative values of the individual component indexes.

Kharbanda [19],[80] presented the idea of a Location Cost Index which was based on three factors:

(i) Cost of raw steel

(ii) Average labour rate

(iii) Productivity

Using the above costs, Kharbanda calculated Location Cost Index values for various countries. These are presented in Table 4.2 where they are compared with the corresponding average values calculated the data presented in Table 2.4.

Table 4.2 Comparison of location cost indexes and factors

Basis: U.S. = 100

COUNTRY	Location Cost Index [19],[80]	Average Location Factor * 100
U.K.	96	90
France	94	92
India	90	118
Italy	95	87
Japan	70	85
W. Germany	98	90

On comparing the values, it can be seen that most of the values are within 10% of the corresponding factor. Agreement seems to depend on the type of country that is being compared. Good agreement is shown Western European countries, but India and Japan show little agreement. One reason for this could be that there is an abundance of information for European countries compared to India, and that Japanese industry enjoys Government incentives.

4.3 ESCALATION AND INFLATION

Costs tend to increase with time. This rate of change is usually called the rate of inflation which can apply to a particular item or a basket of goods. It is used to indicate the current economic climate of a country. The rate of background inflation can have a considerable effect on the costs of construction of a chemical plant when substantial investments are involved over a long period of construction time.

Over the last few years, fluctuating inflation has caused particular problems [66], with chemical plants under construction costing considerably more than estimated. Cost estimates for proposed projects were thus more uncertain because at high rates of inflation estimates were too low and vise versa. Contractors had problems when submitting a fixed-price bid for any project. If the rate of inflation was underestimated then the profit margin would soon be eroded [66]. Purchasers found it very difficult to obtain lump-sum bids for any items for the same reason [67]. Those that were available, contained escalation and escape clauses which made it very difficult for the purchaser to know exactly what the final cost would be. Bonano [68] shows what clauses a contract should contain if the purchaser wanted to be protected from unexpected fluctuations in prices due to inflation.

To understand the effect of inflation it is necessary to break down the cost of a finished product, such as a piece of equipment, into its basic cost components. McMahon [69] states that this cost can be divided into three components:

(i)	Material	2-5%
(ii)	Profit	6-9%
(iii)	Wages	86-92%

This clearly indicates that the changing costs of labour are most likely to cause cost increases. The main reasons for inflation in the U.K. since 1972 are:

(i) Large wage and salary increases.

(ii) Worldwide increase in material costs.

(iii) Considerable increases in energy costs.

This suggests that to control inflation it is necessary to curb wage increases which appears to be the procedure adopted by most Governments. McMahon [69] suggests that to control inflation it is necessary to have full employment in productive occupations. Therefore it is not only limiting wage increases which is necessary, but also the expansion of industry.

5 LABOUR PRODUCTIVITY

5.1 What is Productivity ?

According to Kharbanda and Stallworthy [43a]:

"By definition, so far as we are concerned, productivity is the ratio of output to input, and this is in itself a measure of efficiency."

There are various other definitions of productivity presented in the literature:

(i) Productivity [44] $= \dfrac{\text{Actual time/operation}}{\text{Standard time}}$

Actual time represents the reported labour time used to do a specific labour operation under a set of known condition. The main problem is that a standard time for one group may not be for another. Therefore it would be necessary to establish universal standards for each particular job within each industry.

(ii) "The term 'productivity' is used in the strict sense of how many field welds, electrical connections, etc., are made in a given period of time." [46]

(iii) The American Productivity Center [45] suggests that the Manufacturing Industry should use three definitions of productivity:

(a) Labour productivity: $\dfrac{\text{Production}}{\text{Employees}}$

(b) Capital productivity: $\dfrac{\text{Production}}{\text{Investment}}$

investment: equipment, structures, land inventories

(c) Multiple factor productivity: combination of (a) and (b) by measuring weighted inputs of labour and capital compared with output.

(iv) Statistical sources, such as Government publications, present the index of labour productivity as the index of industrial production divided by the index of industrial employment [47].

The variety of definitions, and the absence of information of approaches shows that productivity is a very difficult subject. To use any productivity measure to compare labour costs within a country or on an international level brings wide ranging problems of uniformity and consistency with different systems. However, it is considered to be a major factor in explaining variations of cost with time and place, and it would be useful to evaluate the effect of productivity and changes in productivity on location factors more accurately.

5.2 Measurement of productivity

5.2.1 Why measure productivity ?

Productivity is used as a means of controlling costs in times of inflation and also as a comparison against competition. It is also considered to be important when the cost of construction of a plant is converted from one country to another, as it is believed to be a major influence of the difference in costs [2]. Ottaviano [48] summarises the interest in measuring productivity as follows: "The quest for higher productivity has been with mankind since the industrial revolution". In simple terms this refers to increased output without a proportionate increase in costs

5.2.2 Measurement

Productivity is a very complex subject and it is very difficult to measure precisely, particularly for the process plant sector. This is supported by Kharbanda [43a] who states that there is no mathematically correct way of measuring productivity and that it is indeed difficult to measure productivity in explicit terms. It is also necessary to have techniques based on mathematical analysis to minimise the emotional evaluation of productivity as there are many individual opinions on how productivity should be measured.

Only one method of calculating the labour productivity factor for the construction of a chemical plant has be found in the literature [15]. The major steps are as follows:

(i) The construction labour cost is calculated for various countries (if comparison is required). This is achieved by obtaining the wages (including benefits) of the various trades used in the construction of a plant and then working out the average wage. This is then reduced to the basis of 1.0 for the U.S. wage. These figures are then adjusted to take other factors into account. (The figures presented in the article are based on 1961 costs.)

(ii) The first correction factor is the number of hours worked, which are reduced to a U.S. base of 1.0.

(iii) The second correction factor is for job duration and mechanisation available to supplement construction labour. (no information is given on how this factor was calculated)

(iv) Using the three values for each country, the labour productivity ratio can be calculated by multiplying the three factors, given above, together.

Every consideration necessary in measuring productivity is covered in a useful list presented by Mark [45]. The list includes construction labour, expatriate supervisory and skilled personnel, and laws and regulations, all of which affect productivity. Two factors that effect productivity are mechanisation and the number of hours worked [15].

> "Labour productivities are dynamic parameters that will vary with the level of economic activity and naturally with the level of construction mechanisation." [49]

Several sources [46],[50] agree that the use of overtime is detrimental to productivity. Blough [51] presents a detailed analysis of the effect of overtime on labour productivity, concluding that productivity falls if overtime is used. The fall is even more drastic if the use of overtime is continued for some time; Blough [51] quotes a drop from 1.0 to 0.65 within 10 weeks. Labour productivity was measured using a fixed standard of measurement of man hours to perform specific functions necessery to accomplish construction operations. The findings of Blough are supported by Edmondson [50]. Table 5.1, presented by Edmondson, indicates that it is preferable to use the eight hour shift system than to allow the work force to do overtime in terms of productivity.

Table 5.1 Productivity versus overtime [50]

Hours worked/week	productivity factor
5 * 8 hour days	1.00
5 * 9 hour days	0.95
5 *10 hour days	0.90
6 * 8 hour days	0.90
6 * 9 hour days	0.90
6 *10 hour days	0.85

Another important factor is the level of supervision [46],[52]. If supervision is adequate and well used, then productivity will be maintained at a reasonable level, and working time lost will be reduced to a minimum. Other factors quoted in the literature which may affect productivity are:

Scheduling of labour resources

Availability of equipment and materials

Degree of congestion during construction

Material storage distances

Changes in weather

Manpower levelling techniques

Availability of labour

The volume of labour used is also an important factor [43b] particularly in countries where Government regulations or union agreements dictate the minimum level of labour to be used.

Kharbanda [19c] suggests that the productivity factor for a given country is a function (ratio) of the wages and benefits within the country relative to the U.S. His results are shown in Table 5.2, which are probably based on the assumption that countries wih low wages employ more unskilled labour and therefore productivity is lower.

Table 5.2 Wage ratio relative to the U.S. as a function of the productivity factor

Wage and benefit ratio	Productivity factor
0.03	7.2
0.05	4.8
0.07	3.8
0.10	3.0
0.15	2.25
0.20	1.8
0.30	1.4
0.4	1.2
0.6	1.1
1.0	1.0

It is also clear from Tables 5.1 and 5.2 that data is presented in the literature in a variety of forms. When comparing data from various sources, care must be taken to ensure that the units are identical, or that the relationships are well understood. Table 5.1 presents labour productivity data in terms of relative efficiency, but Table 5.2 presents labour productivity data in terms of relative man-hours to complete a job.

Productivity in developing countries is also influenced by the use of foreign labour who are employed on a lump-sum contract. Rizk [53] suggests that it would improve productivity if local workers were trained and then supervised closely when working on a construction site. Money would have to be spent on educational facilities but a skilled labour force would soon be available.

To enable labour productivity in the construction industry to be maintained, the use of a 'Productivity Officer' or 'Analyst' is suggested [54]. The object of the job would be to ensure that any shortages were reported directly to purchasers in the construction company who could then replace any materials that are running low. Adequate tools and materials would always be available to complete a job, and efficiency is maintained. Hussain [55] describes in qualitative terms how productivity can be improved and maintained by careful planning of labour, equipment and materials.

5.3 Data Presented in the Literature

Values published in the literature depend on many factors and the definitions of labour productivity vary. An example of how productivity can be used to show an improvement in the economy is exemplified by an increase in productivity (output/employee) of 10% which could occur for two basic reasons:

(1) Output has increased

(2) Number of employees has decreased

Table 5.3 presents a collection of productivity factors published in the literature. On comparing the factors, it can be seen that labour productivity has changed with time. This may be an actual change, or the source, type, or volume of data may have altered thus changing the factor.

5.4 Acceptable Definition of Labour Productivity

In order to compare labour productivity factors from one country to another, it is necessary to have an acceptable and measurable definition. The most likely definition would be the time taken in man-hours to install a major piece of equipment,compared to a standard time, taking into account any special or unusual factors. This definition has already been used by Blough [51] to measure and compare labour productivity. In order to use this definition, it would be necessary to determine the standard number of man hours that are required to carry out a particular task. This would involve a time a motion study, which may not be accepted by the Unions involved.

Table 5.3 World labour productivity factors

COUNTRY	REFERENCE AND YEAR				
	1962 [15]	1964 [59]	1964 [57]	1967 [60]	1968 [61]
Austria		1.60			
Australia	0.96	1.20			1.45
Argentina		3.30			
Belgium		1.45			1.30
Brazil	1.23	2.80			1.90
Borneo					
Canada	1.08	1.10			
Ceylon		3.50			
Chile		2.70			
China					
Columbia					
Czechoslovakia			0.255		
Denmark		1.28			1.3
Finland		1.28	0.268		1.25
France	0.81	1.33			1.25
Holland		1.80	0.39		
India		4.50		4–10	
Indonesia					
Iran		4.00			
Iraq		3.50			
Italy	1.35	1.45			1.35
Japan	1.00	1.90			1.5
Korea					
Korea S.					
Mexico	1.54	2.0			
New Zealand					
Norway		1.23			
Philippines		1.8			
Portugal		3.0			
Saudi Arabia					
Singapore		4.0			
Spain		2.95			
South Africa		1.58			
Sweden		1.13	0.52		1.2
Taiwan		6.8			
Turkey		2.32			
Utd. Arab Emer.					
U.K.	0.69	1.53	0.33		
U.S.A.	1.00		1.00		1.4
Venezuela		1.22			
W. Germany	1.08	1.28			1.2
Yugoslavia		1.4	0.08		

COUNTRY	REFERENCE AND YEAR				
	1969 [29]	1972 [25]	1973 [45]	1974 [58]	1982 [62]
Austria		1.60			
Australia				1.07	0.87
Argentina					
Belgium					0.74
Brazil				2.5	1.78
Borneo			1.8–2.5		
Canada		0.9			0.6
Ceylon				3.5	
Chile				2.41	
China					1.07
Columbia					1.76
Czechoslovakia					
Denmark					
Finland					
France		0.65			0.78
Holland					0.73
India	4–8		3–5	4.5	
Indonesia			2.4–4		
Iran					
Iraq					
Italy		0.75			0.85
Japan		0.65	1.3–2	1.7	0.6
Korea					0.64
Korea S.			1.5–2.5		
Mexico				1.79	
New Zealand					1.01
Norway					0.89
Philippines					
Portugal					
Saudi Arabia					1.0
Singapore			1.7–2.5		0.9
Spain					
South Africa					1.14
Sweden					0.79
Taiwan			2–3		
Turkey				2.06	1.8
Utd. Arab Emer.					1.25
U.K.		0.65	1.2–1.6		1.0
U.S.A.		1.00	1–1.5		1.05
Venezuela			1.7–2.2		1.34
W. Germany		0.75		1.09	0.73
Yugoslavia					

UNITS OF DATA PRESENTED IN TABLE 5.3

Man hours	–	References 29,45,60,61
Relative efficiency (reciprocal of man hours)	–	Reference 15,25,62
Productivity labour ratio	–	Reference 27
Productivity in building of masonry houses	–	Reference 59

6 RESULTS

6.1 Program to Update Location Factors

Equation 3.5 (section 3) shows that an existing location factor at a specific point in time can be updated using exchange rates and cost indexes from its original date to any date where data is available (past, present or future). As a starting basis, the location factors for 34 countries published by Bridgwater [1] in 1979 were used. Exchange rates were obtained from 'International Financial Statistics', published by the World Bank. The only available plant index which covered enough countries, was that published quarterly in 'Process Economics International'. Using the data and equation 3.5, a computer program was written to update the location factor for each available country. The program outputs the results in two forms, both of which will be shown later. A listing of the program is given in Appendix C and data used by the program is listed in Appendix D.

6.2 Results obtained using the program

Tables 6.1 and 6.2 show updated location factors for fourth quarter 1984 based on the 1979 value for 27 countries relative to the United States, and the United Kingdom respectively. The exchange rates listed in the tables are quoted in units of currency per dollar or pounds sterling respectively.

Table 6.1 Updated location factors relative to the United States

COUNTRY	ORIGINAL LOCATION FACTOR AT	EXCHANGE RATE	UPDATED LOCATION FACTOR AT	EXCHANGE RATE
	1st QUARTER 1979		4th QUARTER 1984	
US	1.00	1.0000	1.0000	1.0000
UK	0.90	0.4961	0.6068	0.8050
BELGIUM	1.00	29.2940	0.4700	60.3740
DENMARK	1.00	5.1158	0.4588	10.8010
FRANCE	0.95	4.2680	0.5900	9.1741
GERMANY	1.00	1.8548	0.5594	2.9886
GREECE	0.90	36.4910	0.5644	123.2900
ITALY	0.90	839.1100	0.7076	1859.4000
NETHERLANDS	1.00	2.0030	0.5369	3.3742
NORWAY	1.10	5.0857	0.6812	8.7043
SPAIN	1.20	69.3840	0.8747	167.7800
SWEDEN	1.10	4.3578	0.6280	8.5827
YUGOSLAVIA	0.90	18.6670	0.2038	195.3740
CANADA	1.15	1.1864	1.1126	1.3163
BRAZIL	1.30	21.9390	1.3903	800.0000
MEXICO	0.90	22.7580	0.7254	185.6700
VENEZUELA	1.20	4.2925	0.8658	7.5000
AFRICA(S)	1.10	0.8562	0.8727	1.7966
TUNISIA	1.60	0.4074	0.9038	0.8410
ZAMBIA	1.80	0.7957	1.0487	2.0538
EGYPT	1.20	1.4286	1.2201	1.4286
ISRAEL	1.10	1.9590	0.6330	550.2800
TURKEY	1.00	25.2500	0.3966	429.4900
AUSTRALIA	1.30	0.8795	1.1365	1.1636
INDONESIA	0.90	614.3200	1.0035	1063.2000
JAPAN	0.90	201.4600	0.6758	243.3200
KOREA	0.80	484.0000	0.6946	816.5900
PHILIPPINES	0.80	7.3769	0.8679	19.9590

Table 6.2 <u>Updated location factors relative to the United Kingdom</u>

COUNTRY	ORIGINAL LOCATION FACTOR AT	EXCHANGE RATE 1st QUARTER 1979	UPDATED LOCATION FACTOR AT	EXCHANGE RATE 4th QUARTER 1984
US	1.10	2.0157	1.6315	1.2422
UK	1.00	1.0000	1.0000	1.0000
BELGIUM	1.10	59.0486	0.7668	74.9988
DENMARK	1.10	10.3120	0.7485	13.4174
FRANCE	1.05	8.6031	0.9672	11.3964
GERMANY	1.10	3.7388	0.9127	3.7125
GREECE	1.00	73.5557	0.9302	153.1553
ITALY	1.00	1691.4130	1.1661	2309.8137
NETHERLANDS	1.10	4.0375	0.8760	4.1916
NORWAY	1.20	10.2514	1.1021	10.8128
SPAIN	1.30	139.8589	1.4055	208.4224
SWEDEN	1.20	8.7841	1.0161	10.6617
YUGOSLAVIA	1.00	37.6275	0.3358	242.7006
CANADA	1.25	2.3915	1.7937	1.6352
BRAZIL	1.40	44.2229	2.2207	993.7888
MEXICO	1.00	45.8738	1.1955	230.6460
VENEZUELA	1.30	8.6525	1.3912	9.3168
AFRICA(S)	1.20	1.7259	1.4121	2.2318
TUNISIA	1.75	0.8212	1.4662	1.0447
ZAMBIA	2.00	1.6039	1.7282	2.5513
EGYPT	1.30	2.8797	1.9604	1.7747
ISRAEL	1.20	3.9488	1.0242	683.5776
TURKEY	1.10	50.8970	0.6471	533.5280
AUSTRALIA	1.40	1.7728	1.8153	1.4455
INDONESIA	1.00	1238.2987	1.6537	1320.7453
JAPAN	1.00	406.0875	1.1137	302.2609
KOREA	0.90	975.6098	1.1589	1014.3975
PHILIPPINES	0.90	14.8698	1.4482	24.7938

6.2.1 Comparison of Updated Location Factors For Similar Countries

In order to comment on the results, similar countries have been selected to see how their individual location factors have changed since 1979 with respect to the United States.

(a) Comparison of European countries (West Germany and United Kingdom) and Japan relative to the United States.

The original location factors (1979) and the updated location factors (1984) for West Germany, the United Kingdom, and Japan ralative to the United States, are presented in table 6.3. This data has been extracted from a full list of updated location factors for each country in Tables 6.4,6.5 and 6.6 respectively. On comparing the updated location factors of the three industrialised countries it can be seen that it is a better proposition to build in West Germany than Japan or the United Kingdom relative to the U.S.

Table 6.3 Comparison of updated and original location factors for three major industrial countries relative to the United States

COUNTRY	ORIGINAL	UPDATED (1984)
Japan	0.90	0.676
U.K.	0.90	0.61
W. Germany	1.00	0.56

Figures 6.1 to 6.3 show that costs in West Germany have increased the least with respect to the United States. Figures 6.4 to 6.6 clearly show the effect of the exchange rate on the updating of a location factor. The strength of the Deutschmark has declined considerably against the U.S. dollar but the Yen (Japan) has remained strong. This results in West Germany being regarded as a better location to build a new chemical plant than either of the other two countries.

(b) Scandinavian countries: Norway and Sweden

In 1979, Norway and Sweden were quoted as having identical location factors of 1.10 [1]. The final updated values for the fourth quarter 1984, are also very similar, 0.68 and 0.63 respectively. On comparing Tables 6.7 and 6.8 and also figures 6.7 to 6.10 it can be seen that the plant cost indexes of Norway and Sweden have increased at a similar rate over the past five years,but the Swedish exchange rate has weakened more than the Norwegian exchange rate relative to the U.S. dollar. This suggests that, as far as a U.S. contractor is concerned, Sweden may be a better proposition for investment in terms of cost increases.

(c) Comparison of Canada with the United States

It would be expected that a location factor for Canada relative to the U.S. would change very little with time since the two countries are geographically very close. Table 6.9 shows that in 1979 (first quarter) the location factor was 1.15 and 1.11 in 1984 (fourth quarter). Figure 6.11 shows that costs in Canada have increased more rapidly than those in the U.S. with time, but this is compensated by the weakening of the Canadian currency against the U.S. dollar (see Figure 6.12).

Table 6.4 <u>Quarterly updated location factor and exchange rate for West Germany with respect to the United States</u>

YEAR	COST INDEX BASE	COST INDEX GERMANY	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	117.00	1.85480	1.0000
1979.25	133.00	120.00	1.89470	0.9965
1979.50	140.00	121.00	1.81620	0.9958
1979.75	143.00	123.00	1.76600	1.0192
1980.00	157.00	123.00	1.77340	0.9245
1980.25	153.00	129.00	1.18050	1.4946
1980.50	157.00	130.00	1.77560	0.9759
1980.75	155.00	130.00	1.91120	0.9183
1981.00	161.00	133.00	2.08660	0.8285
1981.25	166.00	135.00	2.27580	0.7478
1981.50	168.00	137.00	2.43270	0.7015
1981.75	172.00	140.00	2.24480	0.7588
1982.00	175.00	143.00	2.34590	0.7289
1982.25	177.00	147.00	2.37800	0.7308
1982.50	178.00	148.00	2.48120	0.7012
1982.75	179.00	148.00	2.50120	0.6917
1983.00	180.00	142.00	2.40780	0.6856
1983.25	181.00	145.00	2.48480	0.6747
1983.50	185.00	147.00	2.64290	0.6291
1983.75	187.00	147.00	2.67760	0.6143
1984.00	187.00	148.00	2.77700	0.5964
1984.25	187.00	149.00	2.70950	0.6154
1984.50	188.00	150.00	2.91890	0.5720
1984.75	189.00	151.00	2.98860	0.5594

Table 6.5 <u>Quarterly updated location factor and exchange rate for the United Kingdom with respect to the United States</u>

YEAR	COST INDEX BASE	COST INDEX UK	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	173.00	0.49610	0.9000
1979.25	133.00	176.00	0.48070	0.9378
1979.50	140.00	180.00	0.44800	0.9777
1979.75	143.00	189.00	0.46320	0.9721
1980.00	157.00	197.00	0.44370	0.9634
1980.25	153.00	201.00	0.43770	1.0225
1980.50	157.00	203.00	0.42000	1.0488
1980.75	155.00	207.00	0.41920	1.0853
1981.00	161.00	212.00	0.43290	1.0362
1981.25	166.00	215.00	0.48650	0.9070
1981.50	168.00	217.00	0.54450	0.8082
1981.75	172.00	220.00	0.53090	0.8208
1982.00	175.00	225.00	0.54140	0.8090
1982.25	177.00	232.00	0.56180	0.7948
1982.50	178.00	233.00	0.57960	0.7694
1982.75	179.00	237.00	0.60620	0.7441
1983.00	180.00	240.00	0.65260	0.6960
1983.25	181.00	242.00	0.64290	0.7085
1983.50	185.00	246.00	0.66220	0.6841
1983.75	187.00	251.00	0.68020	0.6723
1984.00	187.00	255.00	0.72660	0.6394
1984.25	187.00	260.00	0.71590	0.6616
1984.50	188.00	266.00	0.80840	0.5963
1984.75	189.00	271.00	0.80500	0.6068

Table 6.6 <u>Quarterly updated location factor and exchange rate for Japan with respect to the United States</u>

YEAR	COST INDEX BASE	COST INDEX JAPAN	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	134.00	201.46000	0.9000
1979.25	133.00	134.00	217.62000	0.8269
1979.50	140.00	137.00	218.86000	0.7986
1979.75	143.00	137.00	238.62000	0.7171
1980.00	157.00	140.00	243.54000	0.6540
1980.25	153.00	146.00	232.84000	0.7320
1980.50	157.00	148.00	220.05000	0.7651
1980.75	155.00	148.00	210.67000	0.8095
1981.00	161.00	151.00	205.57000	0.8149
1981.25	166.00	153.00	220.00000	0.7483
1981.50	168.00	155.00	231.89000	0.7106
1981.75	172.00	157.00	224.68000	0.7256
1982.00	175.00	158.00	233.49000	0.6906
1982.25	177.00	159.00	244.15000	0.6572
1982.50	178.00	161.00	258.86000	0.6241
1982.75	179.00	162.00	259.68000	0.6225
1983.00	180.00	162.00	235.74000	0.6819
1983.25	181.00	163.00	237.55000	0.6771
1983.50	185.00	165.00	242.53000	0.6568
1983.75	187.00	166.00	234.25000	0.6768
1984.00	187.00	168.00	234.69000	0.6837
1984.25	187.00	170.00	229.61000	0.7072
1984.50	188.00	172.00	243.46000	0.6712
1984.75	189.00	174.00	243.32000	0.6758

Table 6.7 <u>Quarterly updated location factor and exchange rate for Norway with respect to the United States</u>

YEAR	COST INDEX BASE	COST INDEX NORWAY	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	143.00	5.08570	1.1000
1979.25	133.00	144.00	5.16250	1.0830
1979.50	140.00	148.00	5.01860	1.0878
1979.75	143.00	145.00	4.98940	1.0495
1980.00	157.00	148.00	4.94860	0.9837
1980.25	153.00	153.00	4.94250	1.0448
1980.50	157.00	162.00	4.84120	1.1006
1980.75	155.00	158.00	5.02500	1.0475
1981.00	161.00	164.00	5.35010	0.9832
1981.25	166.00	166.00	5.68360	0.9086
1981.50	168.00	173.00	6.08520	0.8739
1981.75	172.00	173.00	5.83910	0.8895
1982.00	175.00	176.00	5.95310	0.8724
1982.25	177.00	180.00	6.07710	0.8641
1982.50	178.00	184.00	6.64160	0.8037
1982.75	179.00	188.00	7.14610	0.7590
1983.00	180.00	190.00	7.10990	0.7667
1983.25	181.00	194.00	7.16970	0.7720
1983.50	185.00	197.00	7.40320	0.7428
1983.75	187.00	201.00	7.50260	0.7398
1984.00	187.00	205.00	7.93200	0.7137
1984.25	187.00	209.00	7.74110	0.7456
1984.50	188.00	213.00	8.36610	0.6993
1984.75	189.00	217.00	8.70430	0.6812

Table 6.8 <u>Quarterly updated location factor and exchange rate for Sweden relative to the United States</u>

YEAR	COST INDEX BASE	COST INDEX SWEDEN	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	141.00	4.35780	1.1000
1979.25	133.00	148.00	4.37460	1.1415
1979.50	140.00	149.00	4.21050	1.1343
1979.75	143.00	152.00	4.20530	1.1343
1980.00	157.00	156.00	4.21820	1.0571
1980.25	153.00	158.00	4.24810	1.0909
1980.50	157.00	161.00	4.15180	1.1084
1980.75	155.00	167.00	4.30020	1.1244
1981.00	161.00	170.00	4.55390	1.0405
1981.25	166.00	172.00	4.87690	0.9534
1981.50	168.00	172.00	5.30180	0.8666
1981.75	172.00	177.00	5.52110	0.8364
1982.00	175.00	188.00	5.73620	0.8404
1982.25	177.00	190.00	5.90020	0.8164
1982.50	178.00	190.00	6.15690	0.7780
1982.75	179.00	192.00	7.33710	0.6561
1983.00	180.00	200.00	7.40940	0.6730
1983.25	181.00	206.00	7.53690	0.6777
1983.50	185.00	206.00	7.80600	0.6401
1983.75	187.00	210.00	7.91620	0.6366
1984.00	187.00	215.00	8.12790	0.6348
1984.25	187.00	219.00	8.00220	0.6568
1984.50	188.00	222.00	8.40730	0.6303
1984.75	189.00	227.00	8.58270	0.6280

Table 6.9 Quarterly updated location factor and exchange rate for Canada with respect to the United States

YEAR	COST INDEX BASE	COST INDEX CANADA	EXCHANGE RATE	CALCULATED LOCATION FACTOR
1979.00	132.00	149.00	1.18640	1.1500
1979.25	133.00	154.00	1.15810	1.2085
1979.50	140.00	158.00	1.16330	1.1726
1979.75	143.00	162.00	1.17470	1.1657
1980.00	157.00	165.00	1.16430	1.0910
1980.25	153.00	170.00	1.17030	1.1476
1980.50	157.00	174.00	1.15860	1.1562
1980.75	155.00	178.00	1.18390	1.1724
1981.00	161.00	184.00	1.19360	1.1573
1981.25	166.00	189.00	1.19860	1.1481
1981.50	168.00	192.00	1.21170	1.1400
1981.75	172.00	197.00	1.19180	1.1616
1982.00	175.00	202.00	1.20890	1.1541
1982.25	177.00	206.00	1.24450	1.1304
1982.50	178.00	207.00	1.24980	1.1247
1982.75	179.00	211.00	1.23150	1.1569
1983.00	180.00	213.00	1.22730	1.1654
1983.25	181.00	213.00	1.23100	1.1555
1983.50	185.00	215.00	1.23280	1.1394
1983.75	187.00	217.00	1.23850	1.1325
1984.00	187.00	220.00	1.28730	1.1046
1984.25	187.00	223.00	1.29270	1.1150
1984.50	188.00	226.00	1.31390	1.1059
1984.75	189.00	229.00	1.31630	1.1126

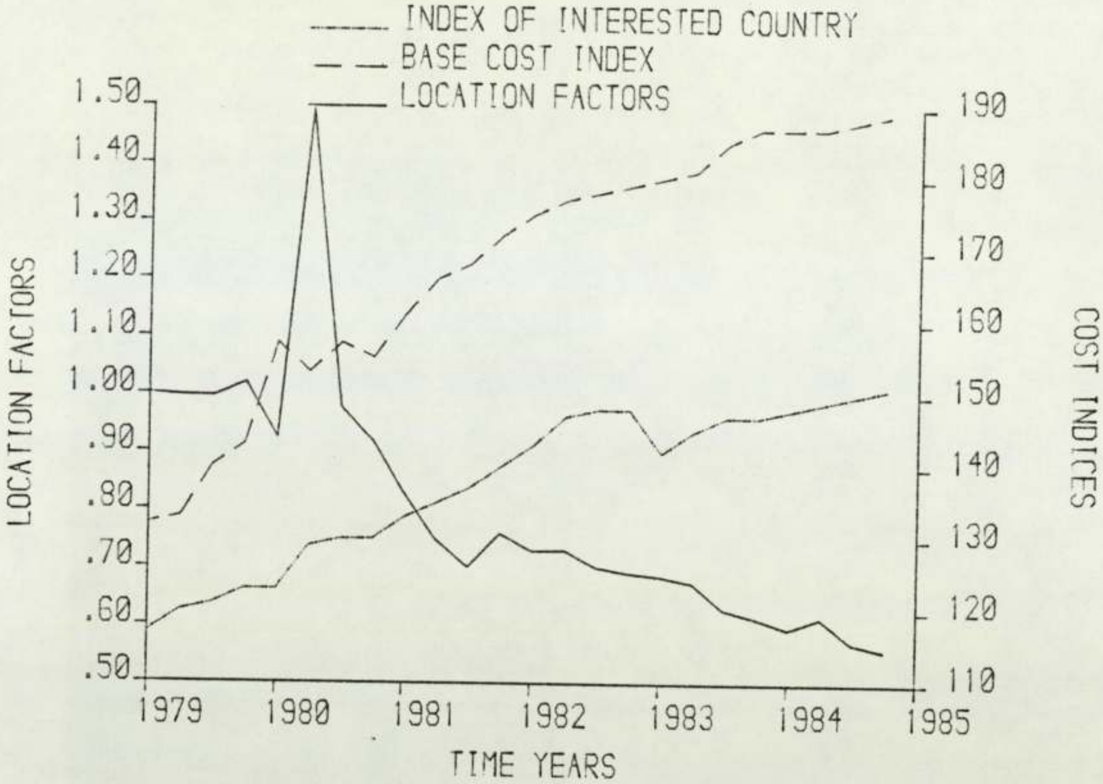

Figure 6.1 <u>Cost Index of the U.S. and West Germany and the updated location factor against time</u>

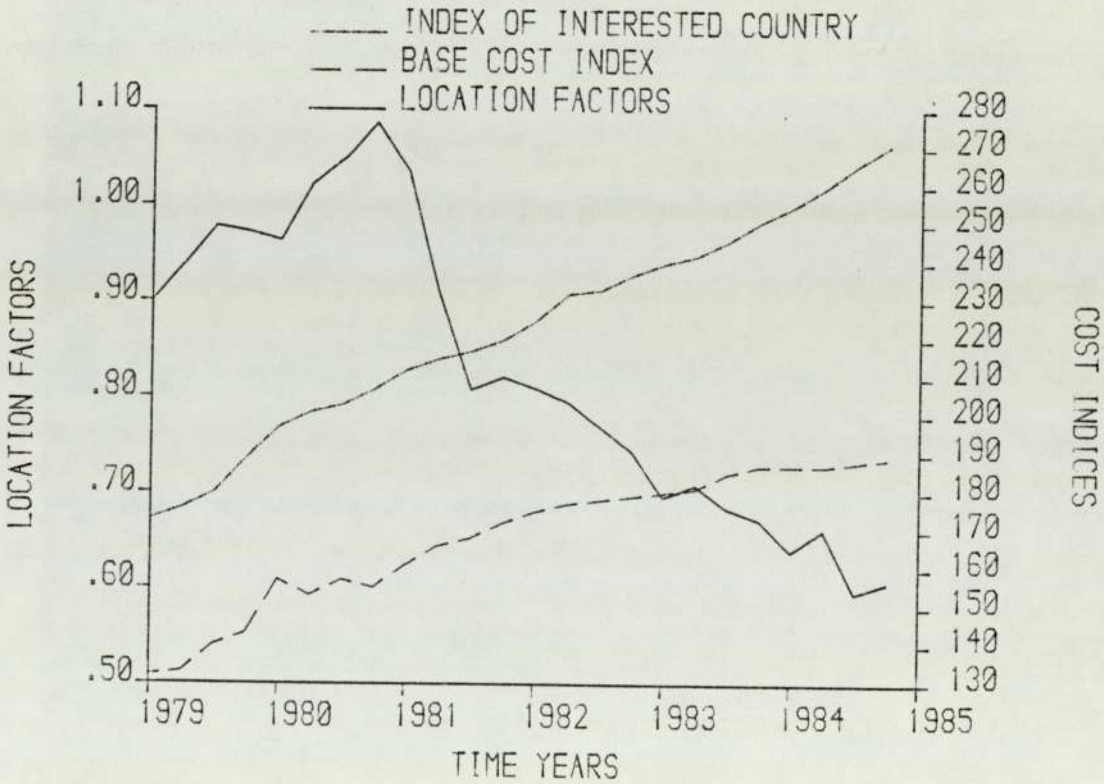

Figure 6.2 <u>Cost Index of the U.S. and U.K. and the updated location factor against time</u>

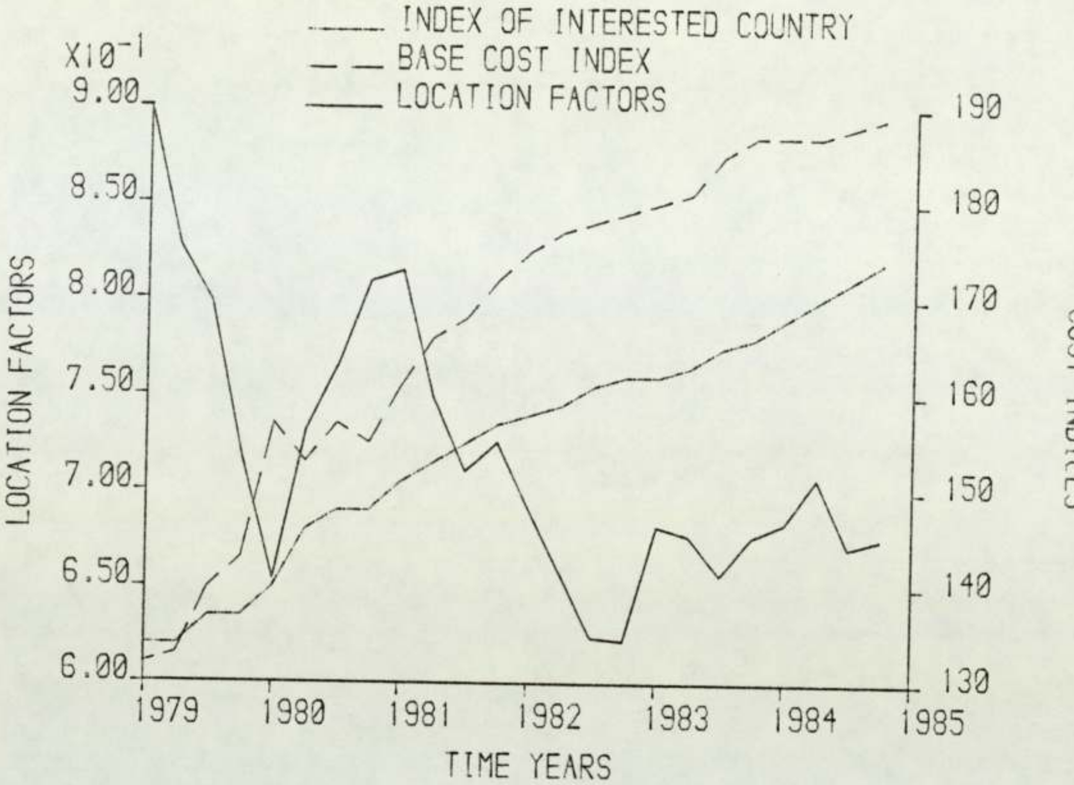

Figure 6.3 Cost index of the U.S. and Japan and the updated location factor against time

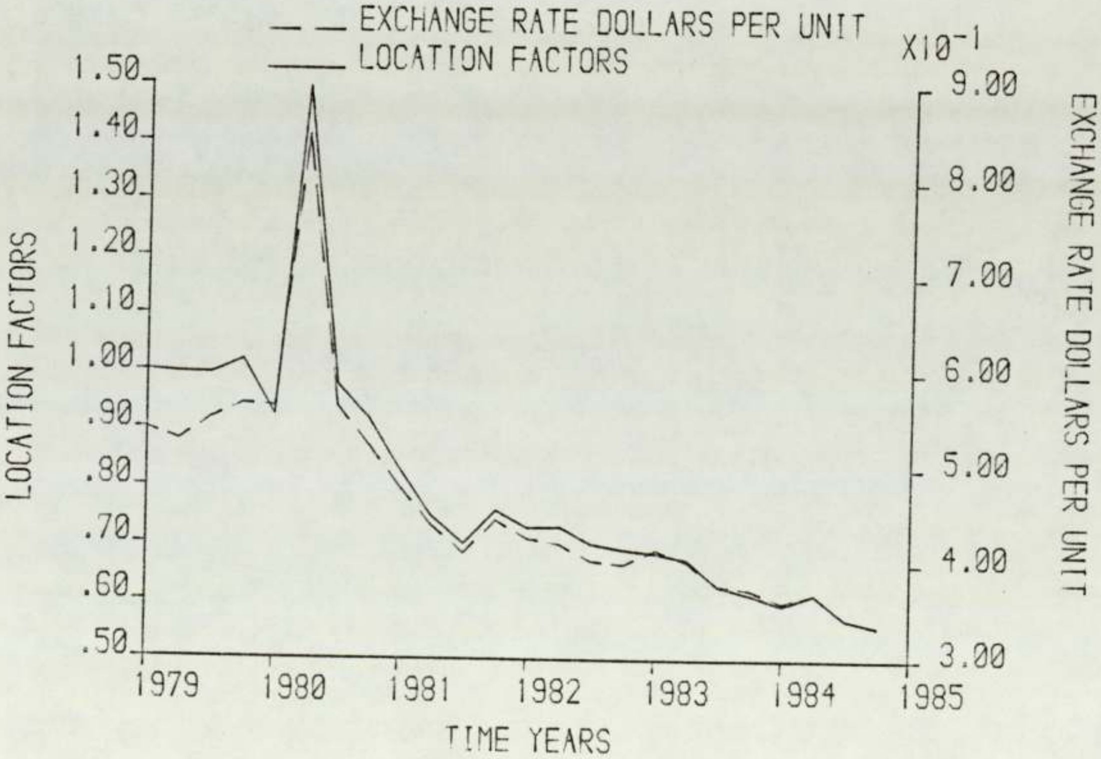

Figure 6.4 Exchange rate of U.S./West Germany and the updated location factor against time

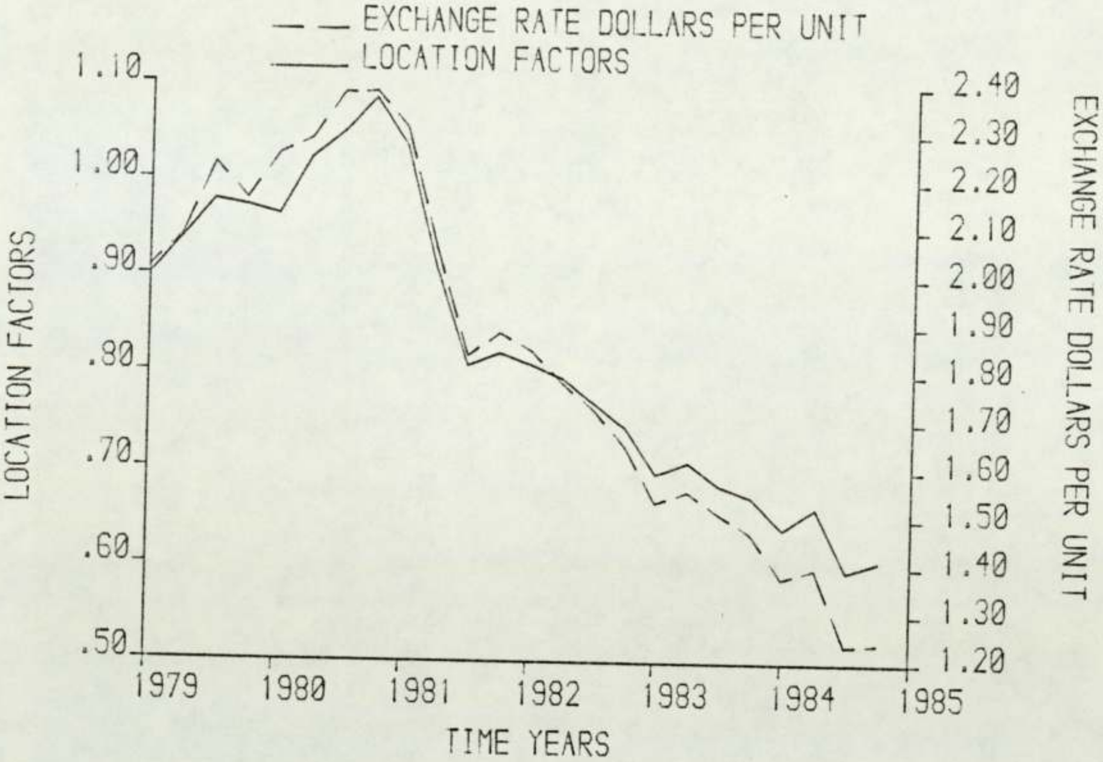

Figure 6.5 Exchange rate of U.S./U.K. and the updated location factor against time

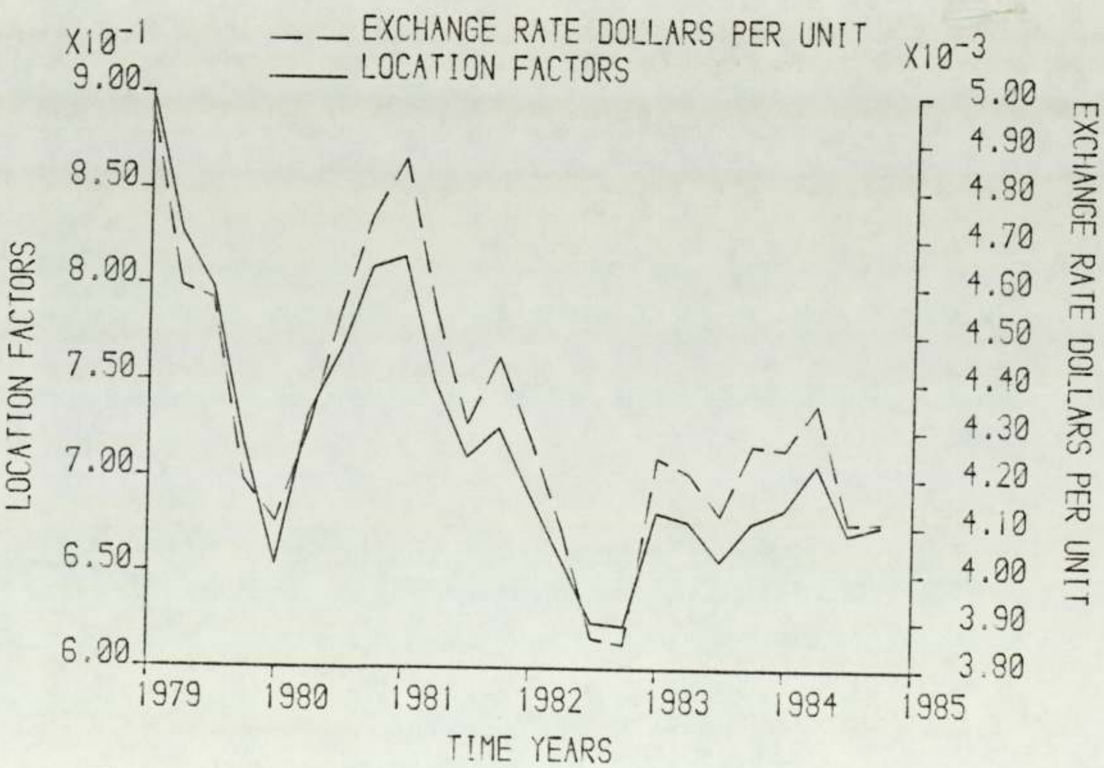

Figure 6.6 Exchange rate of U.S./Japan and the updated location factor against time

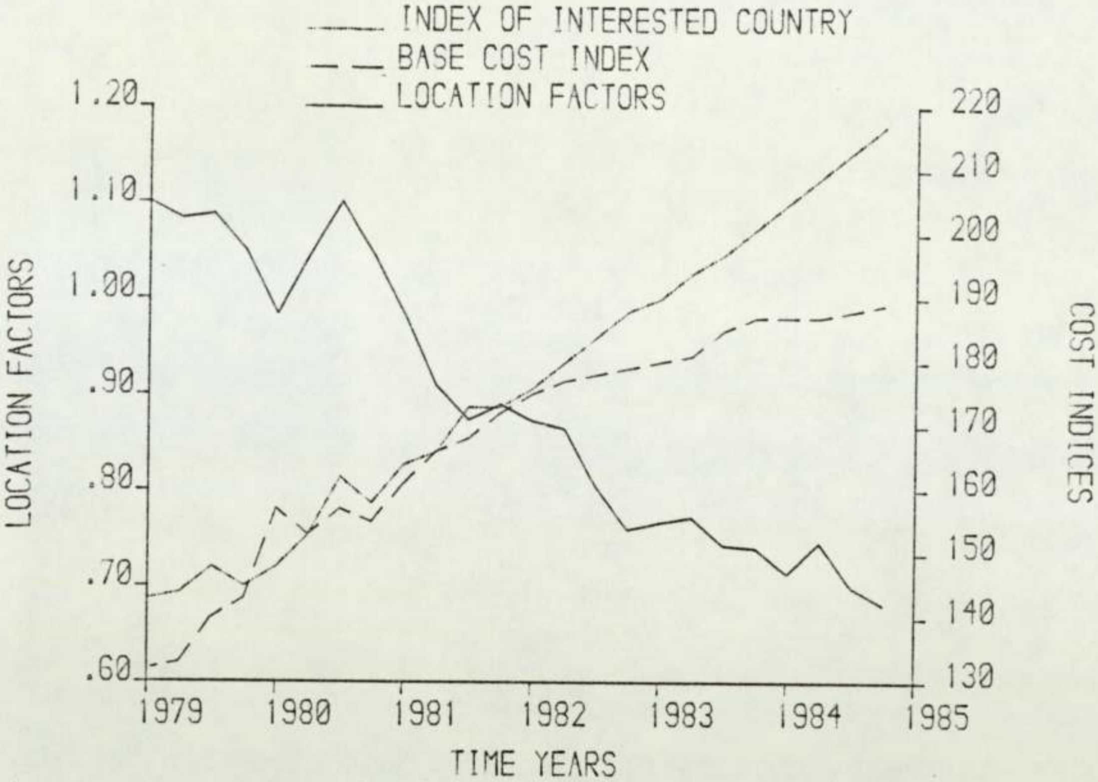

Figure 6.7 Cost index of the U.S. and Norway and the updated location factor against time

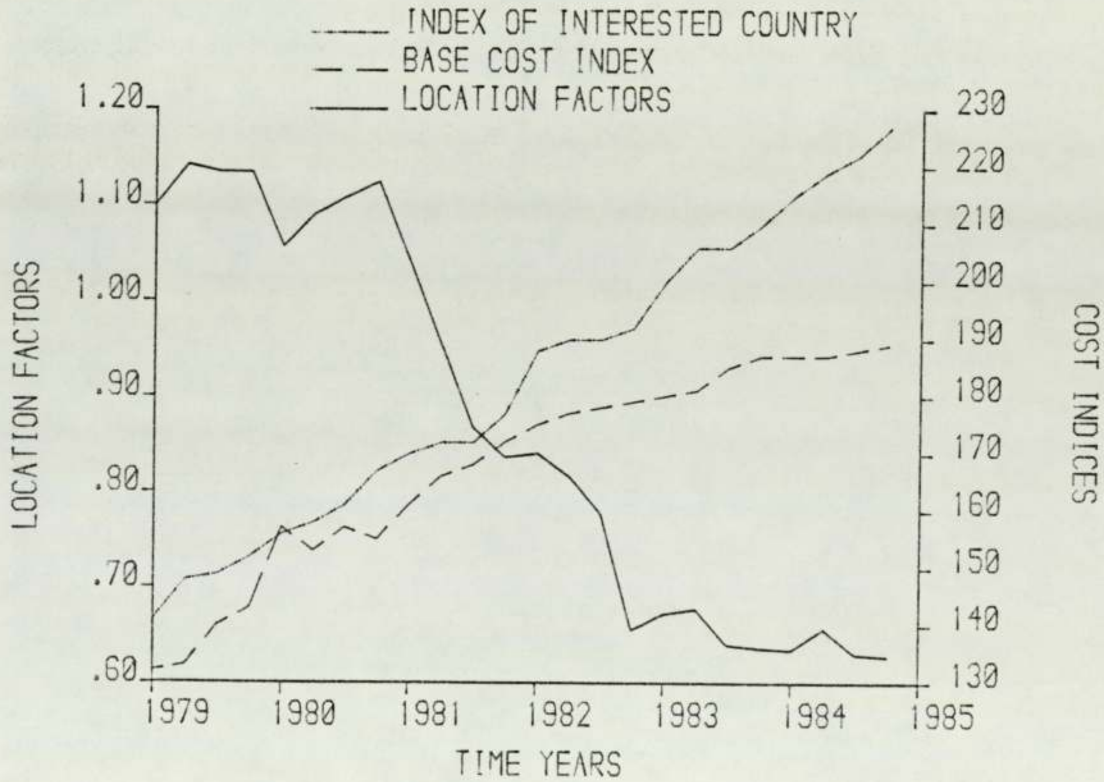

Figure 6.8 Cost index of the U.S. and Sweden and the updated location factor against time

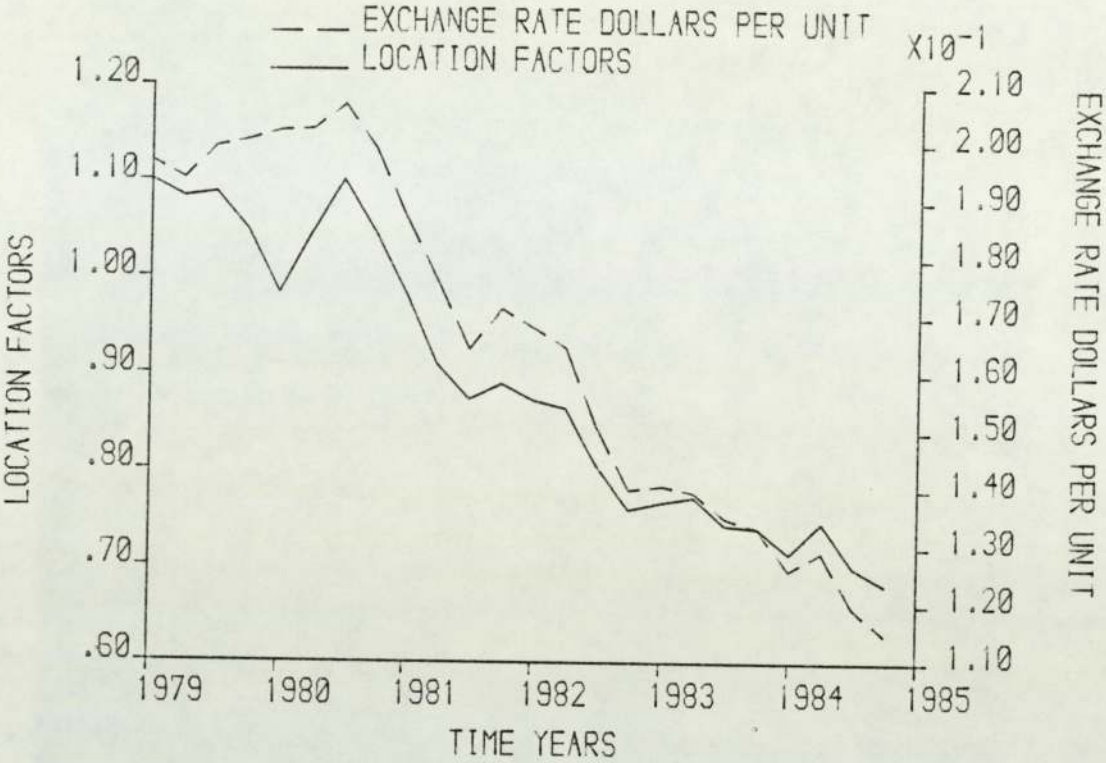

Figure 6.9 Exchange rate of U.S./Norway and the updated location factor against time

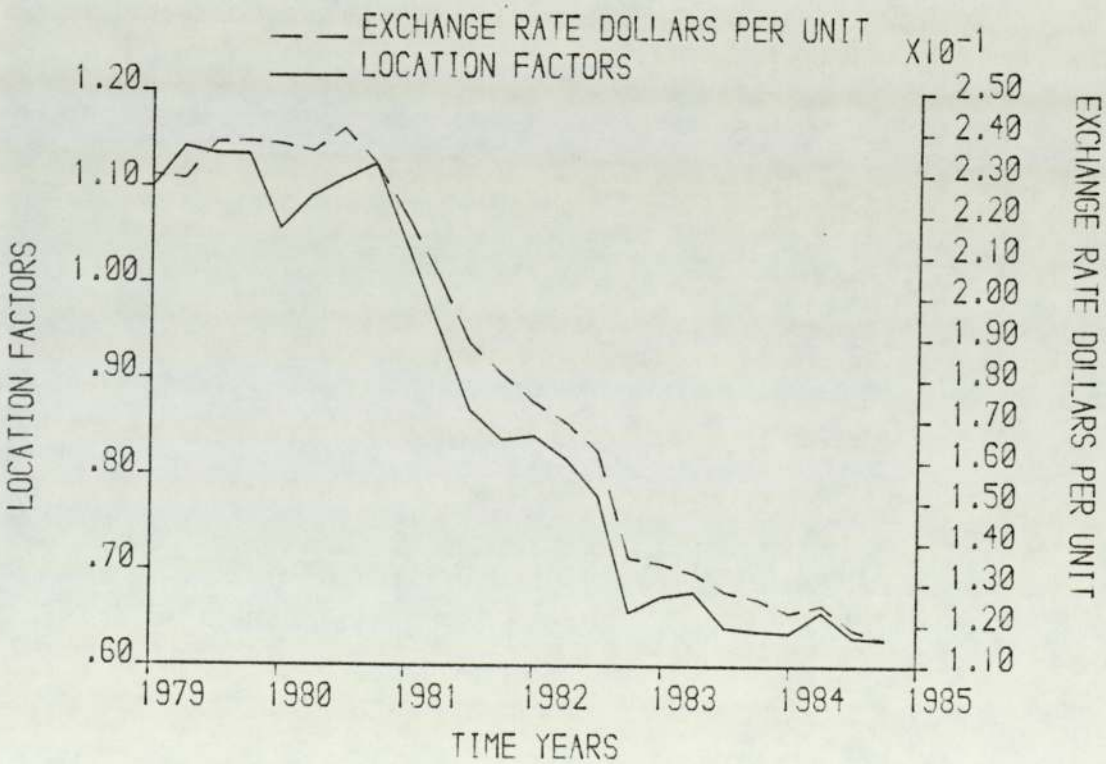

Figure 6.10 Exchange rate of U.S./Sweden and the updated location factor against time

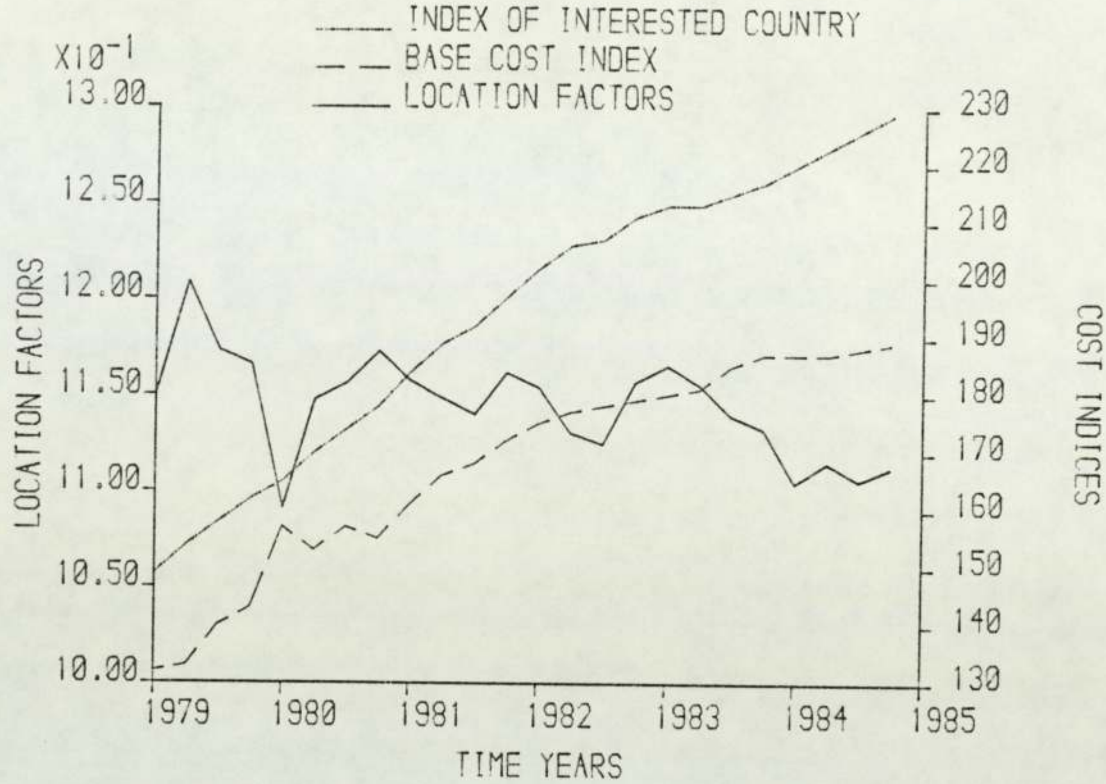

Figure 6.11 Cost index of the U.S. and Canada and the updated location factor against time

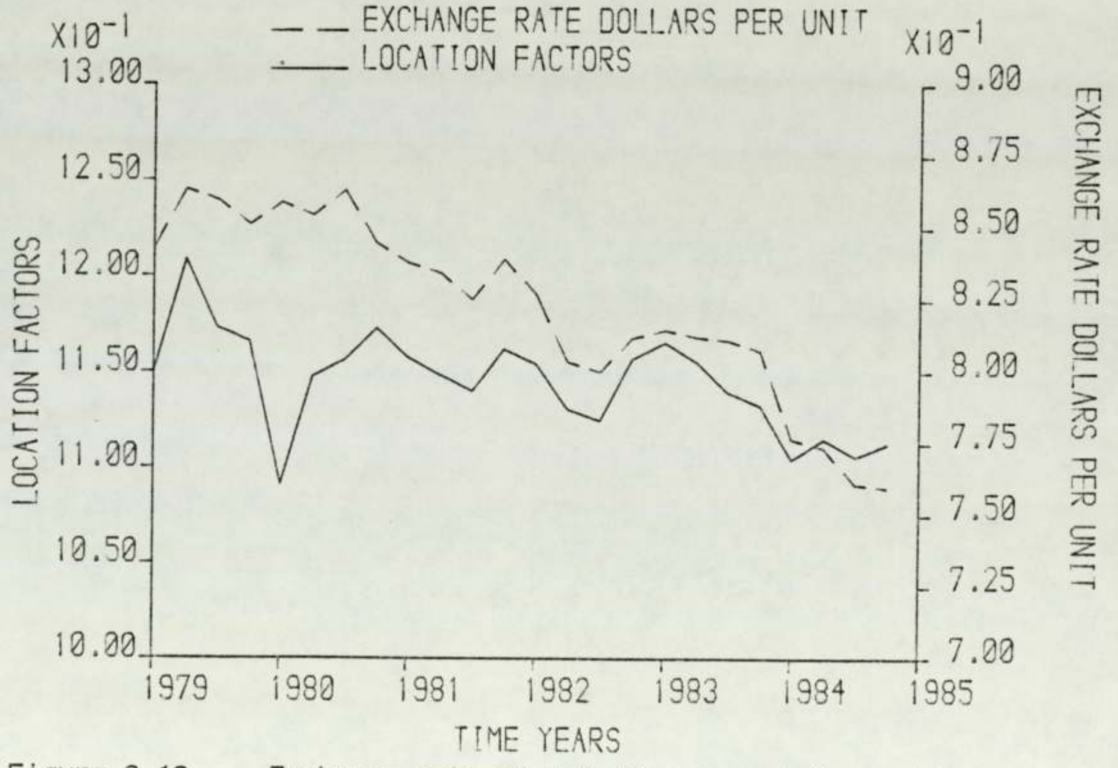

Figure 6.12 Exchange rate of U.S./Canada and the updated location factor against time

6.3 Effect of Exchange Rate on Location Factors

The exchange rate between two countries is very important when determining the value of a location factor. Consider, for example, the possible effect the exchange rate has had on the location factor between the U.K. and the U.S. In 1979 the location factor (U.K./U.S.) was quoted as 0.9 and the exchange rate (first quarter) was 0.496 Pounds sterling/Dollar. In 1984 (fourth quarter) the exchange rate was 0.805 Pounds sterling/Dollar (see Table 6.5). If all other influences are assumed to be negligible, then the location factor becomes:

$$0.9 * \frac{0.496}{0.805} = 0.55 \text{ (U.K./U.S.)}$$

$$\text{or } 1.82 \text{ (U.S./U.K.)}$$

The time scale is five years but the same significant effect could happen over a shorter time period when the exchange rate changes considerably such as in the first 8 months of 1985 when the value of the pound compared to the dollar changed by 40%. This may be the time period between the initial cost comparison being carried out to the final decision being taken. The fluctuation of the exchange rate is clearly shown by Figure 6.13. A report in the Daily Telegraph [64] states that the U.S. Dollar is probably 40 percent, on average, overvalued against four other major currencies. Table 6.10 shows what the exchange rate should be [64].

Table 6.10 Overvaluation of the Dollar [64]

CURRENCY	OVER VALUATION 17-6-85 percent	EQUILIBRIUM RATE PER $ June 1985	ACTUAL RATE PER $ 17-6-85	RISE NEED PER $ percent
US Dollar	40	-	-	-
Yen	-12	196	249	27
Deutschmark	-13	2.04	3.06	50
French Franc	- 5	6.64	9.34	42
Sterling	+15	1.52	1.28	19

The only answer to the problem of a fluctuating exchange rate is to be able to successfully predict its movements. If this could be achieved then profit could be made by simply buying and selling world currencies using the forward and spot markets. Forecasting the behaviour of exchange rates is difficult. Duffy and Giddy [63] describe in detail the difficulties forecasting exchange rates. Figure 6.13 shows how the exchange rate between the United Kingdom and the United States has fluctuated since 1972. Banks, such as Barclays, do attempt to predict the exchange rate one year in advance. An example of this is given in Table 6.11 forecasts exchange rates for January 1986 based on the exchange rates for the previous two years [82].

Table 6.11 Forecasting the movement of currencies against pound sterling [82]

CURRENCY	JAN 84(av.)	JAN 85(av)	FORECAST
U.S. Dollar	1.33	1.13	1.14–1.20
Deutschemark	3.79	3.58	3.30–3.50
Yen	316.6	287.3	259–279
French Franc	11.64	10.96	10.58–10.98
Swiss Franc	3.14	3.00	2.72–2.92
Italian Lira	2340	2203	2168–2218

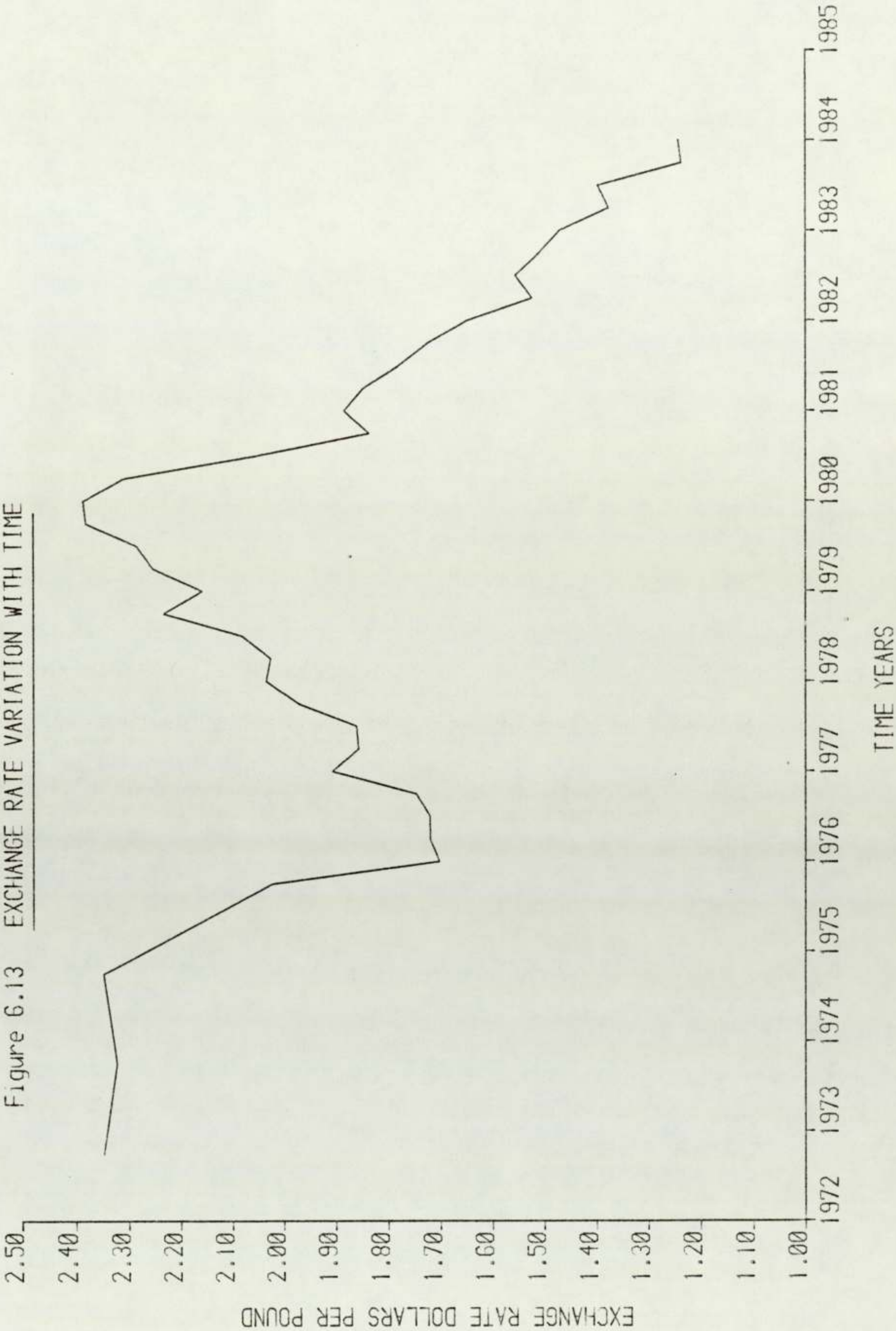

Figure 6.13 EXCHANGE RATE VARIATION WITH TIME

6.4 Location Weighted Exchange Rate

Figure 6.10 shows that the location factor and exchange rate fluctuate considerably in a short period of time. It would be preferable if this fluctuation could be limited. To achieve this, the location factor and the exchange rate could be combined to form a Location Weighted Exchange Rate. A location weighted exchange rate is defined as the location factor for a given pair of country, multiplied by the exchange rate that it is tied to. It has been suggested that for a given country, it may be constant (B.P.). Tables 6.12 to 6.15 show location weighted exchange rates for the United Kingdom, West Germany, Japan and Canada relative to the United States. Table 6.12 shows that the location weighted exchange rate for the United Kingdom relative to the United States has increased from about 0.45 to about 0.49. The data presented in the tables is also shown graphically in Figures 6.14 to 6.17. The figures were obtained from Tables 6.4, 6.5, 6.6 and 6.9 by multiplying the exchange rate by the location factor, ensuring that the units of the exchange rate used were correct, i.e. U.S. Dollars per unit of currency.

Equation (3.5) (see Chapter 3) states that:

$$LF_n = LF_t * \frac{CI(B)_n}{CI(B)_t} * \frac{CI(A)_t}{CI(A)_n} * \frac{ER_n}{ER_t}$$

Rearranging:

$$LF_n * (1/ER_n) = LF_t * \frac{CI(B)_n}{CI(B)_t} * \frac{CI(A)_t}{CI(A)_n} * (1/ER_t) \quad ....(6.1)$$

Where $LF_n * (1/ER_n)$ is the Location Weighted Exchange Rate (LWER)

Equation (6.1) can be rearranged to give:

$$LWER = G * \frac{CI(B)_n}{CI(A)_n} \quad .....(6.2)$$

$$\text{Where } G = LF_t * \frac{CI(A)_t}{CI(B)_t} * (1/ER_t)$$

Therefore, from equation (6.2), it can be deduced that the location weighted exchange rate is only dependent on the ratio of the current cost indexes at the time of the update. If the inflation rate in both countries being compared is similar, then the location weighted exchange rate will be relatively constant. Table 6.16 shows the ratio of cost indexes for the United Kingdom, Japan, West Germany and Canada relative to the United States. If cost indexes can be forecast then the likely behaviour in the value of the location weighted exchange rate can be estimated. This would be easier than attempting to forecast the behaviour of currency exchange rates.

A simple linear method of extrapolating data is Newton's forward difference formula which is described and illustrated by Jenson [80]. Results obtained using this method are presented in Tables 6.17 and 6.18. The results obtained are very much dependent on the starting data. Trial runs have shown that if the starting point of the data used in the method occurs when the difference between two quarters is unexpectantly low, then the resultant forecasts are low. An example of this is presented in Table 6.18 which compares predicted values, obtained using the method, against actual values. Plant cost indexes of 1980 and 1981 were used to predict the plant cost index for the following three years. It can be seen that that the difference between the predicted values and the actual values is increasing each year. A more complex method may produce better results.

Table 6.12 Location weighted exchange rate for the United Kingdom relative to the United States

YEAR	EXCHANGE RATE	CALCULATED LOCATION FACTOR	LOCATION WEIGHTED EXCHANGE RATE
1979.00	0.49610	0.9000	0.447
1979.25	0.48070	0.9378	0.451
1979.50	0.44800	0.9777	0.438
1979.75	0.46320	0.9721	0.450
1980.00	0.44370	0.9634	0.427
1980.25	0.43770	1.0225	0.448
1980.50	0.42000	1.0488	0.440
1980.75	0.41920	1.0853	0.455
1981.00	0.43290	1.0362	0.448
1981.25	0.48650	0.9070	0.441
1981.50	0.54450	0.8082	0.440
1981.75	0.53090	0.8208	0.436
1982.00	0.54140	0.8090	0.438
1982.25	0.56180	0.7948	0.446
1982.50	0.57960	0.7694	0.446
1982.75	0.60620	0.7441	0.451
1983.00	0.65260	0.6960	0.454
1983.25	0.64290	0.7085	0.455
1983.50	0.66220	0.6841	0.453
1983.75	0.68020	0.6723	0.457
1984.00	0.72660	0.6394	0.465
1984.25	0.71590	0.6616	0.472
1984.50	0.80840	0.5963	0.482
1984.75	0.80500	0.6068	0.488

Table 6.13 Location weighted exchange rate for West Germany relative to the United States

YEAR	EXCHANGE RATE	CALCULATED LOCATION FACTOR	LOCATION WEIGHTED EXCHANGE RATE
1979.00	1.85480	1.0000	1.855
1979.25	1.89470	0.9965	1.888
1979.50	1.81620	0.9958	1.808
1979.75	1.76600	1.0192	1.800
1980.00	1.77340	0.9245	1.639
1980.25	1.18050	1.4946	1.764
1980.50	1.77560	0.9759	1.733
1980.75	1.91120	0.9183	1.755
1981.00	2.08660	0.8285	1.729
1981.25	2.27580	0.7478	1.702
1981.50	2.43270	0.7015	1.706
1981.75	2.24480	0.7588	1.703
1982.00	2.34590	0.7289	1.710
1982.25	2.37800	0.7308	1.738
1982.50	2.48120	0.7012	1.740
1982.75	2.50120	0.6917	1.730
1983.00	2.40780	0.6856	1.651
1983.25	2.48480	0.6747	1.676
1983.50	2.64290	0.6291	1.663
1983.75	2.67760	0.6143	1.644
1984.00	2.77700	0.5964	1.656
1984.25	2.70950	0.6154	1.667
1984.50	2.91890	0.5720	1.670
1984.75	2.98860	0.5594	1.672

Table 6.14 Location weighted exchange rate for Japan relative to the United States

YEAR	EXCHANGE RATE	CALCULATED LOCATION FACTOR	LOCATION WEIGHTED EXCHANGE RATE
1979.00	201.46000	0.9000	181.3
1979.25	217.62000	0.8269	179.9
1979.50	218.86000	0.7986	174.8
1979.75	238.62000	0.7171	171.1
1980.00	243.54000	0.6540	159.3
1980.25	232.84000	0.7320	170.4
1980.50	220.05000	0.7651	168.3
1980.75	210.67000	0.8095	170.5
1981.00	205.57000	0.8149	167.5
1981.25	220.00000	0.7483	164.6
1981.50	231.89000	0.7106	167.8
1981.75	224.68000	0.7256	163.0
1982.00	233.49000	0.6906	161.2
1982.25	244.15000	0.6572	160.4
1982.50	258.86000	0.6241	161.5
1982.75	259.68000	0.6225	161.6
1983.00	235.74000	0.6819	160.7
1983.25	237.55000	0.6771	160.8
1983.50	242.53000	0.6568	159.2
1983.75	234.25000	0.6768	158.5
1984.00	234.69000	0.6837	160.4
1984.25	229.61000	0.7072	162.4
1984.50	243.46000	0.6712	163.4
1984.75	243.32000	0.6758	164.4

Table 6.15 <u>Location weighted exchange rate for Canada relative to the United States</u>

YEAR	EXCHANGE RATE	CALCULATED LOCATION FACTOR	LOCATION WEIGHTED EXCHANGE RATE
1979.00	1.18640	1.1500	1.364
1979.25	1.15810	1.2085	1.399
1979.50	1.16330	1.1726	1.364
1979.75	1.17470	1.1657	1.369
1980.00	1.16430	1.0910	1.270
1980.25	1.17030	1.1476	1.343
1980.50	1.15860	1.1562	1.339
1980.75	1.18390	1.1724	1.388
1981.00	1.19360	1.1573	1.381
1981.25	1.19860	1.1481	1.376
1981.50	1.21170	1.1400	1.381
1981.75	1.19180	1.1616	1.384
1982.00	1.20890	1.1541	1.395
1982.25	1.24450	1.1304	1.407
1982.50	1.24980	1.1247	1.406
1982.75	1.23150	1.1569	1.425
1983.00	1.22730	1.1654	1.430
1983.25	1.23100	1.1555	1.422
1983.50	1.23280	1.1394	1.404
1983.75	1.23850	1.1325	1.403
1984.00	1.28730	1.1046	1.422
1984.25	1.29270	1.1150	1.441
1984.50	1.31390	1.1059	1.453
1984.75	1.31630	1.1126	1.464

Table 6.16 Cost index ratio for the United Kingdom Japan, West Germany and Canada relative to the United States (Souce - PEI)

YEAR AND QUARTER		COST INDEX RATIO RELATIVE TO THE U.S. U.K.	JAPAN	WEST GERMANY	CANADA
1979	1	1.31	1.015	0.886	1.129
	2	1.32	1.008	0.902	1.156
	3	1.28	0.978	0.864	1.128
	4	1.32	0.958	0.860	1.132
1980	1	1.31	0.892	0.783	1.050
	2	1.29	0.954	0.843	1.111
	3	1.29	0.943	0.828	1.108
	4	1.28	0.954	0.839	1.148
1981	1	1.32	0.938	0.826	1.143
	2	1.29	0.922	0.813	1.138
	3	1.29	0.923	0.815	1.143
	4	1.28	0.913	0.814	1.122
1982	1	1.28	0.903	0.817	1.154
	2	1.31	0.898	0.830	1.164
	3	1.31	0.904	0.831	1.163
	4	1.32	0.905	0.827	1.179
1983	1	1.33	0.900	0.788	1.183
	2	1.34	0.900	0.801	1.177
	3	1.33	0.892	0.795	1.178
	4	1.34	0.888	0.786	1.160
1984	1	1.36	0.898	0.791	1.176
	2	1.39	0.909	0.796	1.193
	3	1.41	0.915	0.798	1.202
	4	1.43	0.921	0.799	1.211

Table 6.17 Forecasted cost indexes for the United Kingdom and the United States

Based on data from 1982 to 1984.

YEAR AND QUARTER		UNITED STATES	UNITED KINGDOM	RATIO
1985	1	190	277	1.46
	2	191	282	1.48
	3	192	288	1.50
	4	193	293	1.52
1986	1	194	299	1.54
	2	195	304	1.56
	3	196	310	1.58
	4	197	315	1.60
1987	1	198	321	1.62
	2	199	326	1.64
	3	200	332	1.66
	4	201	337	1.68

Table 6.18 Comparison of predicted and actual values

YEAR AND QUARTER		PREDICTED	ACTUAL
1982	1	222	225
	2	225	232
	3	227	233
	4	230	237
1983	1	232	240
	2	235	242
	3	237	246
	4	240	251
1984	1	242	255
	2	245	260
	3	247	266
	4	250	271

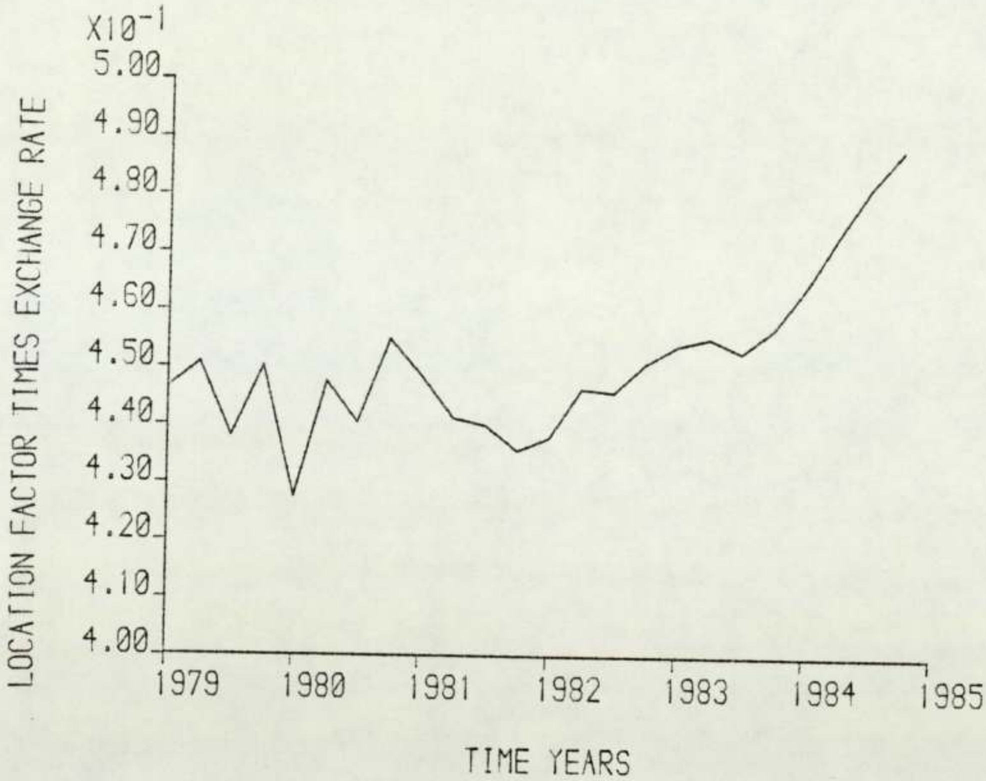

Figure 6.14 Location weighted exchange rate for the United Kingdom relative to the United States

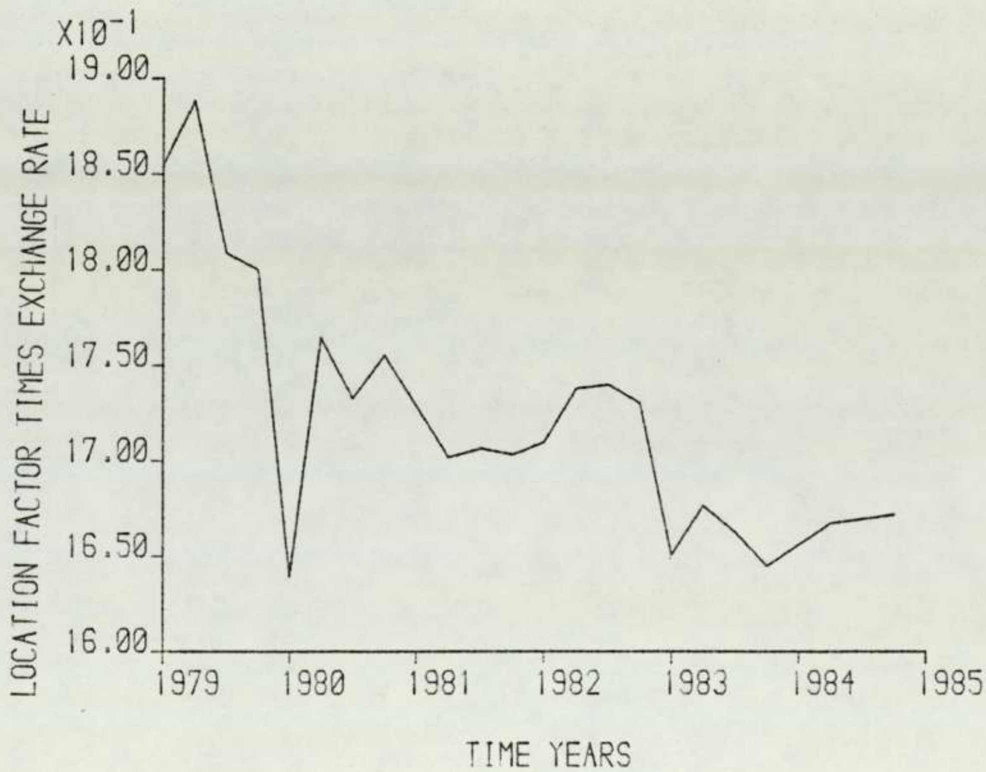

Figure 6.15 Location weighted exchange rate for West Germany relative to the United States

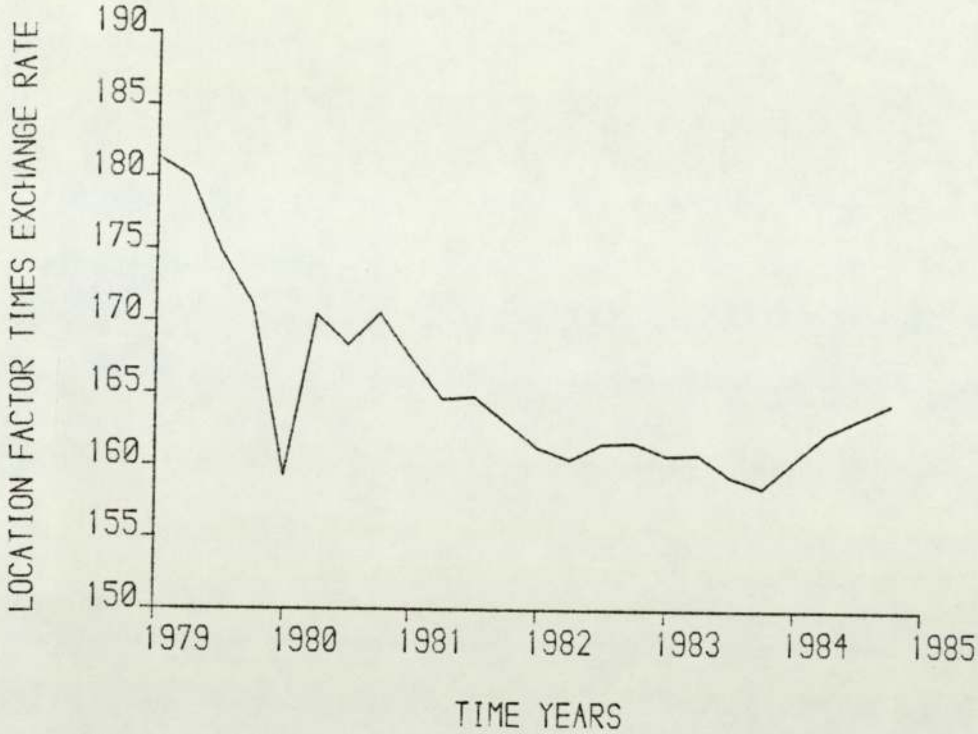

Figure 6.16 Location weighted exchange rate for Japan relative to the United States

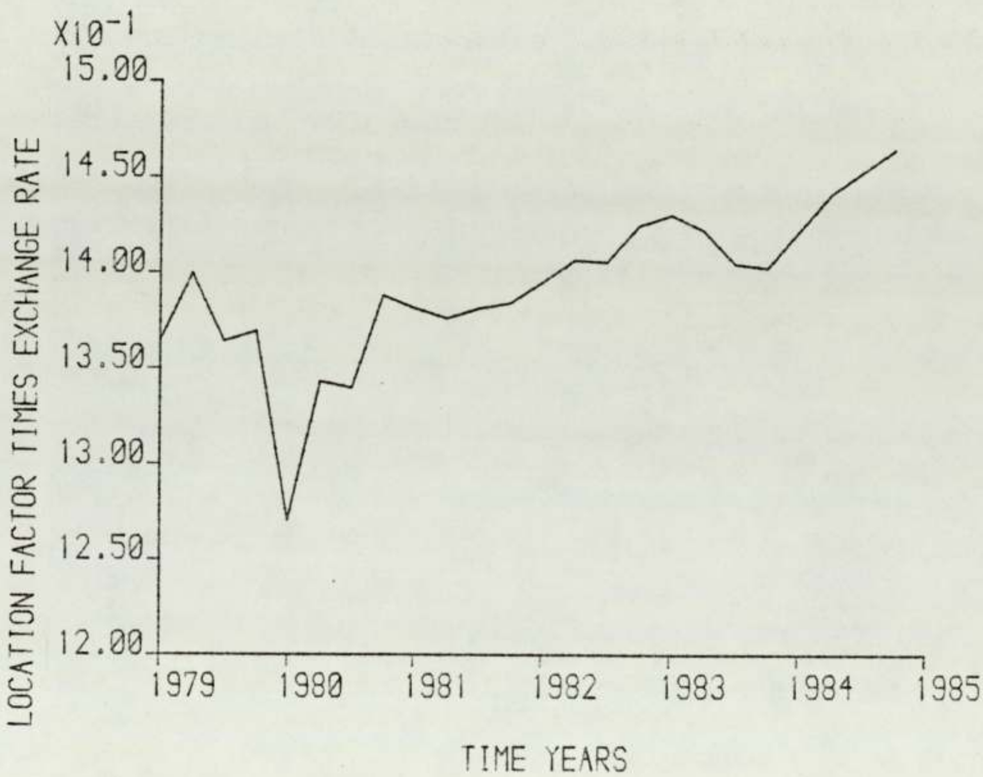

Figure 6.17 Location weighted exchange rate for Canada relative to the United States

6.5 Capital Cost Model of a Chemical Plant

To improve the method of updating location factors, the capital cost of a chemical plant could be broken down into five cost components as described in section 2.1.2, and each individual component updated usinga relevant cost index. Appendix A contains the capital cost analyses that have been found in the literature. Using this data, a five component capital cost model of a chemical plant has been derived. This is presented in Table 6.19.

Table 6.19 Five component cost model of a chemical plant

COMPONENT	PERCENTAGE
Major Equipment items	33.5%
Labour (erection)	14.8%
Process Materials	18.8%
Indirect cost (home office, field expenses)	23.1%
Buildings	9.8%

For each cost component, there are a several indexes which may be suitable to represent the way in which the cost of that component has changed with time:

Main equipment items:

Chemical Engineering Index - individual indexes given for fabricated equipment and process machinery.

Nelson Refinery Inflation Index (Oil and Gas journal)	- indexes given for pumps, compressors and heat exchangers.

Labour

Engineering News Record	- Common labour index for states in U.S. World wage rates for specific skills.
Association of Cost Eng.	- Erection labour index
Chemical Engineering	- Construction labour index for U.S.
Process Engineering	- Mechanical Engineering construction labour index

Process materials

Engineering News Record	- Materials index
Chemical Engineering	- Indexes for pipes, instrumentation and control
Oil and Gas Journal	- Materials Index

Indirects:

The field expenses cost component is difficult because of the variety of costs which it covers. For Home Office costs there are two indexes which could be of use:

Association of Cost Eng.	- Administrative, technical and clerical salaries.

Chemical Engineering	-	Engineering and manpower.

<u>Buildings:</u>

Association of Cost Eng.	-	Civil and building materials.
Chemical Engineering	-	Building index.
Process Engineering	-	Civil engineering and buidings.
Engineering News Record	-	Building cost index, constuction cost index. (Both have labour cost included.)

In order to complete the work, it would be necessary to find many more capital cost analyses, possibly from an industrial source, although this approach was tried but due to the current economic climate, was unsuccessful.

7 CONCLUSION

The method of updating location factors would have considerably greater value if the results obtained using it are compared against more recent location factors derived from actual plant costs. This is not possible using data presented in the literature. A contractor would be a useful source of such information. Unfortunately, due to the current economic climate, contractors are unwilling to spend the capital to collate the necessary information. More importantly, they are unwilling generally to divulge highly confidential cost data. The basis of the method is mathematically sound, but it would be useful if feedback could be obtained from contractors and companies concerning the results obtained. The location weighted exchange rate attempts to limit the effect of a fluctuating exchange rate and to enable the forecasting of future values easier. It has been shown that the location weighted exchange rate is directly related to the ratio of the plant cost index for the two countries being compared. Therefore, if the plant cost index accurately describes the changes in plant costs, then the location weighted exchange rate would be a useful way of presenting data in the literature. In general, location factors published in the literature are of little use because they give no indication of the source of information, time, or exchange rate used. A standard definition of a location factor, and a standard method of presenting location factors in the literature must be adopted.

8 RECOMMENDATIONS FOR FURTHER WORK

The capital cost models of a chemical plant presented in the thesis are very basic and use data from a wide range of time periods. Capital cost models could be derived for a variety of time periods to investigate the variation of each of the main cost components with time. These changes could then be compared against the changes that have taken place in the component indexes of available plant cost indexes.

The method of updating existing location factors could be improved by using a relevant cost index for each of the main cost components of a chemical plant. It is also unlikely that equipment and materials used in the construction of a chemical plant, will be purchased from a single source. Therefore, the method could be further developed to allow the user to decide what percentage of each individual cost component is purchased, or hired from a particular location.

When constructing a chemical plant, companies tend to purchase equipment from a variety of countries around the world. An investigation could be carried out to determine if equipment costs vary when purchasing identical equipment from a variety of countries for the construction of a chemical plant at a given location.

APPENDIX A COST ANALYSES OF CHEMICAL PLANTS PUBLISHED IN THE LITERATURE

A computer on-line search located only two references in this area, both of which, have already been presented in Table 2.1. In order to formulate the model of a chemical plant, which is to be used to update location factors, it is necessary to collect and analyse the available cost breakdowns of chemical plants presented in the literature. The following are the capital cost breakdowns that have been found in the literature:

(i) Aries and Newton [7] (1955)

COMPONENT	PERCENTAGE
Purchased equipment	25
Installation	11
Piping	10
Instrumentation	2
Insulation	2
Electrical	3
Buildings	8
Land and yard improvements	2
Utilities	9
Engineering and construction	14
Contractors fee	4
Contingency	10
Total	100

(ii) Wells [70] (1977)

Cost breakdowns, dated 1973, are given for two types of processes:

Liquid processing (8 cases)

Liquid/solid processing (2 cases)

Averages of the data are given in the table below.

COMPONENT	LIQUID PROC. PERCENTAGE	SOLID/LIQ. PROC PERCENTAGE
Equipment	28.1	38.4
Installation	1.5	2.6
Buildings	14.1	17.6
Foundations	3.3	1.9
Structures	4.4	3.7
Pipework	14.0	7.2
Electrical	5.8	4.6
Insulation and paint	3.1	1.6
Instruments	6.5	1.4
Engineering	19.2	21.0

(iii) Jelen [11] (1970)

Jelen presents percentage ranges for each cost component of a chemical plant based on 6 references published in the literature, and also a typical cost breakdown.

COMPONENT	TYPICAL BREAKDOWN	RANGE
Main Equipment items	24	15–40
Installation	7	6–16
Process piping	7	2–25
Instruments	3	1– 8
Electrical	4	1– 5
Buildings, process	2	0.5–15
Utilities	9	3–20
General service		0.5–10
Building, general	4	4–14
Receiving, shipping, storage	5	2–12
Painting and insulation	2	
Foundations	1	
Site improvements	3	
Land	1	
Engineering, overheads		8–16
Contingency	10	9–22
Engineering and supervision	8	
Construction expenses	8	
Contractors fee	2	

(iv) Institute of Chemical Engineers [41] (1977)

Typical cost distributions are given for 5 projects:

A U.K. greenfield site

B Overseas greenfield site

C U.K. existing site

D U.K. existing site

E Overseas existing site

COMPONENT	A	B	C	D	E	Av.
Equipment	45	22	38	41	30	35.2
Electrical	3	4	5	6	3	4.2
Instrumentation	4	3	7	4	4	4
Piping	10	6	7	10	9	8.4
Structural steel	3	3	8	2	4	4
Miscellaneous	2	4	6	5	3	4
Civils	5	19	6	5	8	8.6
Mech. erection	18	27	8	6	25	16.8
Home Office	10	12	15	21	16	14.8

(v) Gallagher J.T. [18] (1969)

Based on figures presented for a 1963 Gulf Coast ethylene plant:

COMPONENT	PERCENTAGE
Materials and equipment	43.75
Electrical	1.44
Piping	8.2
Instruments	4.72
Structural	1.17
Civil materials	2.81
Insulation	4.29
Painting	0.62
Labour	11.72
Construction field expenses	5.47
Testing	0.55
Home Office	15.62

- derived by dividing component cost by total plant cost.

(vi) Roberson [14] (1979)

Published in 1979, the breakdown represents a conceptualised model of a chemical plant.

COMPONENT	PERCENTAGE
Main equipment	33
Instruments	7
Piping	15
Electrical	4
Civil	10
Painting/insulation	2
Design	29

(vii) Clerk [61] (1963)

The cost breakdown was presented as an example of how multiplying factors were calculated to give the installed cost of process equipment for other plants.

COMPONENT	PERCENTAGE
Main fabricated equipment	25
Pipework	12.5
Foundations, buildings	15
Erection costs	27.5
Indirect costs	20

(viii) Pfeifer V.F. et al. [71]

A comparison of costs is presented for two chemical plants which different capital costs for the production of Dialdehyde Starch.

COMPONENT	10 Million PERCENTAGE(a)	2.1 Million PERCENTAGE(b)
Land and improvements	1.88	2.55
Building	7.55	7.85
Equipment delivered	39.25	37.78
Installation	9.81	9.46
Piping and wiring	11.32	11.86
Other construction costs	11.32	11.86
Contingency, engineering, and contractor fees	18.87	18.64

(ix) Lambe [72] (1978)

Lambe presents a cost analysis of a typical U.S. plant:

COMPONENT	PERCENTAGE
Major materials and equipment delivered	40
Bulk materials	19
Field construction labour	23
Consruction tools and equip.	3
Field supervision	3
Home office services	12

(x) Lang H.J. [73]

The data is based on the cost breakdowns of 14 chemical plants built in the time period 1942-7.

COMPONENT	SOLID PERCENTAGE	SOLID/FLUID PERCENTAGE	FLUID PERCENTAGE
Home office, field expenses etc.	21.7	22.7	26
Yard improvements	6.9	1.9	1.4
Buildings	10.8	8.6	6.1
Process equipment	46	42.9	32.3
Piping	3.4	9.4	21.3
Electrical	6.1	5.5	3.9
Service facilities	5.1	9	9

(xi) Bauman [26] (1962)

COMPONENT	PERCENTAGE U.S.	PERCENTAGE U.K.
Equipment, spares	28.2	25.1
Site development	2.5	2.7
Buildings	18.1	24.6
Piping	14.4	10.3
Insulation	2.4	2.0
Instrumentation	5.0	3.1
Electrical	6.3	7.6
Painting	1.2	0.4
Services	10.6	8.5
Engineering and supervision	11.3	15.7

(xii) Massa [15] (1983)

The cost analysis of a typical U.S. Gulf Coast chemical plant is given in the article; it is used in a method to calculate location factors.

COMPONENT	PERCENTAGE
Labour	33.05
Materials and equipment	53.45
Indirect and Home Office	13.50

(xiii) Stallworthy [24] (1963)

The data listed below was originally published in 1961 by Mc Gower [74].

COMPONENT	FLUID/GAS PERCENTAGE	MIXED PERCENTAGE	SOLIDS PERCENTAGE
Process equipment	55.5	60.6	64.5
Electrical	2.8	3.0	6.5
Steel structures	2.8	3.0	3.2
Instruments	8.3	6.2	6.5
Insulation/paint	2.8	3.0	3.2
Piping	25.0	21.2	12.9
Temporary facilities	2.8	3.0	3.2

For the U.K., based on the total material cost given above:

Total materials	100.00%
Freight etc.	10.78%
Erection	68.86%
Piling	0.60%
Design	17.36%

(xiv) Nelson [16] (1973)

The cost breakdown for a U.S. Gulf Coast plant is the basis of a method which illustrates how a location factor can be constructed.

COMPONENT	PERCENTAGE
Delivered equipment and materials	40.5
Labour	22.5
Contractor cost	25.9
Job duration and engineering	11.1

(xv) Wagialla [4] (1984)

As with Nelson [16], the cost breakdown is used to illustrate a method of calculating location factors. The data is more recent, 1984, than that of Nelson, 1973.

COMPONENT	PERCENTAGE
Machinery and equipment delivered	52
Installation	20
Building, substructure	18
Miscellaneous (fees, commisioning)	4
Engineering (Home office, field expenses)	6

(xvi) Korevaar J. [75] (1976)

The cost components for the Dutch Annual Composite Cost Index.

COMPONENT	PERCENTAGE
Process equipment	33
Piping	8
Electrical	3
Instrumentation	3
Architecture, civil and steel structures	6
Engineering, construction labour and overheads	42

In the same article, cost analyses are listed to show how the cost breakdown has changed.

COMPONENT	1968 PERCENTAGE	1972 PERCENTAGE
Process equipment	38.76	35.09
Piping	11.24	9.82
Electrical	5.42	4.91
Instrumentation	7.75	7.72
Erection	15.9	18.6
Insulation/painting	5.81	5.26
Building, steel structure	11.24	13.68
Miscellaneous costs	3.88	4.92

(xvii) Kay S.R. et al. [76] (1981)

Cost analyses based on the data obtained by Eady and Boyd in 1964. 80 chemical, petrochemical, and petroleum plants were studied. Costs were allocated to five components. These now constitute the basis of the Association of Cost Engineers Plant Cost Index.

COMPONENT	A	B	C	D
Mechanical and electrical material	54.3	57.8	54.1	62.1
Civil and building mat.	5.5	5.8	5.4	6.2
Erection labour	23.3	22.0	23.8	19.2
Administration, technical and clerical salaries	10.9	9.2	10.8	8.1
Construction equipment and transportation	6.0	5.2	5.9	4.4

(xviii) Cran J. [38] (1983)

Process Engineering Cost Index

COMPONENT	PERCENTAGE
Mechanical engineering	37
Electrical engineering	8
Civil engineering and buildings	10
Site engineering	19
Overheads	26

As a comparison, Cran also presents the following analyses, published in the literature:

COMPONENT	Eady and Boyd	NEDO
Mechanical Eng.	37	32
Electrical, instruments	10	8
Civil Eng., buildings	7	14
Site Engineering	20	19
Overheads	26	27

(xix) Gerrard A.M. [77] (1984)

Chemische industrie Cost Index

COMPONENT	PERCENTAGE
Machinery	33
Pipes and valves	16
Instrumentation	9
Insulation, painting	5
Electrical	7
Structures	15
Engineering fees	15

(xx) Kay S.R. [78] (1983)

Canadian process plant cost indexes

CMPP – Chemical and Mineral Process Plant Index

CPP – Chemical and Petrochemical Plant Index

COMPONENT	CMPP PERCENTAGE	CPP PERCENTAGE
Plant and equipment	54.2	47
Site costs	16.6	29
Buildings	13.5	9
Engineering and admin.	15.7	15

(xxi) Chemical Engineering Index

COMPONENT	PERCENTAGE
Equipment,machinery	35.4
Piping	12.2
Steelwork	6.1
Electrical	3.0
Instrumentation	4.3
Erection labour	22.0
Buildings	7.0
Engineering,supervision	10.0

(xxii) Grosselfinger [25] (1962)

U.S. ethylene and nitric acid plant

COMPONENT	ETHYLENE(a)	NITRIC ACID(b)
Equipment,material	60	75
Labour	23	8
Engineering etc.	17	17

(xxiii) Jacks R.L. and Eddy T.A. [66] (1975)

Plant cost breakdown for a typical petroleum project based on data presented in terms of hard and soft currency.

COMPONENT	PERCENTAGE
Material	34.61
Subcontracts	38.93
Labour	13.84
Engineering	4.15
freight	5.87
Home Office	2.60

(xxiv) Wallace [17] (1976)

The cost of a chemical plant built in the U.S. Gulf Coast is presented, from which, the percentage cost of each component was calculated

COMPONENT	PERCENTAGE
Equipment	38
Labour	12.4
Materials	21.6
Indirect	26.4
Buildings	1.6

Indirect cost can be divided into:

Field expenses	14.46
Home Office	11.97

Table A1 - Summary of cost analyses of chemical plants presented in the Literarature

REFERENCE	[7]	[70]		[11]	[41]				
YEAR	1955	1973		1970	1977				
COMPONENT		(a)	(b)		A	B	C	D	E
Equipment	28.1	28.1	38.4	30.5	45	22	35	41	30
labour	12.4	1.5	2.6	8.1	22	20	33	27	21
Materials	19.1	29.4	14.8	21.3	18	27	8	6	25
Indirect	31.4	19.2	21	32.1	10	12	15	21	16
Building	9.0	21.5	23.2	8.0	5	19	6	5	8

REFERENCE	[18]	[14]	[61]	[71]		[73]		
YEAR	1969	1979	1963			1947		
COMPONENT				(a)	(b)	(S)	(S/F)	(F)
Equipment	43.75	33	25	40	38.8	52.2	48.2	36.1
Labour	11.72		27.5	10	9.7			
Materials	19.27	28	12.5	23.1	24.1	10.9	16.7	28.1
Indirect	21.64	29	20	19.2	19.1	24.7	25.5	29
Building	3.98	10	15	7.7	8.1	12.2	9.6	6.8

REFERENCE	[72]	[26]		[15]	[24]		
YEAR	1978	1962		1983	1963		
COMPONENT		U.S.	U.K.		(F)	(S/F)	(S)
Equipment	40	32.4	28.3	53.45	33.6	36.2	38.1
Labour	23			33.05	34.9	34.9	34.9
Materials	19	33.7	26.3		21.3	18.6	16.6
Indirect	18	13.1	17.7	13.5	10.2	10.3	10.4
Building		20.8	27.7				

REFERENCE	[16]	[4]	[75]	[76]			
YEAR	1973	1984	1976	1981			
COMPONENT				a	b	c	d
Equipment	40.05	52	33	59.8	63.6	59.5	68.3
Labour	22.5	20		23.3	22.0	23.8	19.2
Materials			19				
Indirect	37	10	42	16.9	14.4	16.7	12.5
Building		18	6				

REFERENCE	[77]	[25]		[10]	[9]	[8]	[17]
YEAR	1984	1962		1964	1963	1960	1976
COMPONENT		(a)	(b)				
Equipment	48	60	75	27.4	27.7	27.7	38
Labour		23	8	10.7	12.0	10.8	12.4
Materials	30			16.7	16.9	16.9	21.6
Indirect	15	17	17	35.7	36.2	36.2	26.4
Buildings	15			9.5	7.2	8.4	1.6

APPENDIX B CAPITAL COST ANALYSIS

From the summary of the data in Appendix A, presented in Table A1, it is possible to derive various capital cost models to represent the cost of a chemical plant. The standard model, of five components, was calculated from the applicable data listed in Table A1, and is presented below (it is also presented in Table 6.19):

COMPONENT	PERCENTAGE
Equipment	33.5
Labour	14.8
Materials	18.8
Indirects	23.1
Buildings	9.8

It is also possible to convert this into a six component model by separating the indirect component cost into two components: Home Office, and Field expenses. The data presented below gives the percentage of the Home Office cost component of the Indirect cost component as quoted in the literature:

SOURCE	HOME OFFICE
Jelen [11]	28.66
Gallagher [18]	27.82
Lambe [72]	33.33
Wallace [17]	45.00

Averaging the above values gives a weighted percentage for the Home Office cost component of 32.33%. Therefore, the Indirect cost component of 23.1% in the five component capital cost model becomes:

Home Office	6.9%
Field Expenses	16.2%

Table B1 presents a three component cost model based on the applicable data presented in Table A1.

Table B1 <u>Data for the three component model</u>

REFERENCE	[15]	[24]	[16]	[72]	AVERAGE
COMPONENT					
Material and equipment	53.45	54.8	40.5	59	53.55
Labour	33.05	34.9	22.5	23	27.29
Indirect	13.5	10.3	37.0	18	19.16

On averaging the figures presented in Table B1 and comparing them with the adjusted standard model (see Table B2), it can be seen that the major difference is the labour cost component. As different sources of information were used to obtain the values then some differences are very likely. The five component cost model was adjusted to take into account the removal of the buildings cost component of 9.8% of the total capital cost from the five component capital cost model.

Table B2 Comparison of three component model and the adjusted standard five component model

Material and equipment	53.55	57.98
Labour	27.29	16.41
Indirect	19.16	25.61

APPENDIX C COMPUTER PROGRAM TO UPDATE LOCATION FACTORS

```
C ****************************************************************

C     THIS PROGRAM CALCULATES CURRENT LOCATION FACTORS
C     FOR 32 COUNTRIES USING EXISTING VALUES (1979),
C     EXCHANGE RATES AND COST INDICES;USING THE SAME
C     DATA LOCATION FACTORS CAN BE CALCULATED FOR A
C     SPECIFIC COUNTRY FOR EACH QUARTER SINCE 1979.
C     ALL CALCULATED DATA IS PLOTTED AGAINST TIME
C     USING GINO ROUTINES.

C ****************************************************************

C.....DEFINE VARIABLES

      REAL USB(35),UKB(35),CI(35,24),ER(35,24),TIME(24),ARRAY(24),
     +W(24),X(24),Y(24),Z(24),LF,V(35),NLF,LFER(24),LMAX,LMIN

      INTEGER SELB,SELC,NAME(18)

      CHARACTER*11 CNTRY(35)
      CHARACTER*1 AGAIN

C ****************************************************************
C     READ IN DATA (COUNTRY,EXISTING LOCATION FACTORS
C     COST INDICES AND EXCHANGE RATES.
C ****************************************************************

C.....N IS THE NUMBER OF SETS OF QUARTERLY DATA

      N = 24

      DO 20 I=1,32
          READ(10,1100) CNTRY(I),USB(I),UKB(I)
              DO 10 J=1,N
                  READ(12,*) CI(I,J)
                  READ(13,*) ER(I,J)
                  IF (J.EQ.1) THEN
                      TIME(1) = 1979
                  ELSE
                      TIME(J) = TIME(J-1) + 0.25
                  ENDIF
   10         CONTINUE
   20 CONTINUE

C ****************************************************************
C     OUTPUT DATA IN TABULAR FORM TO FILENAME DATAOUT
C ****************************************************************

      WRITE(20,*) '1'
      WRITE(20,2700)
      WRITE(20,2800)
      WRITE(20,2900)
```

```
      WRITE(20,2700)

      DO 22, J=1,24
          WRITE(20,3000) TIME(J),ER(2,J),ER(3,J),ER(4,J),ER(5,J),
     +    ER(6,J),ER(7,J)
   22 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3100)
      WRITE(20,2700)

      DO 23, J=1,24
          WRITE(20,3200) TIME(J),ER(8,J),ER(9,J),ER(10,J),
                         ER(11,J),ER(12,J),ER(15,J)
   23 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3300)
      WRITE(20,2700)

      DO 24, J=1,24
          WRITE(20,3400) TIME(J),ER(16,J),ER(17,J),ER(18,J),
                         ER(19,J),ER(20,J)
   24 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3500)
      WRITE(20,2700)

      DO 26, J=1,24
          WRITE(20,3600) TIME(J),ER(21,J),ER(22,J),ER(23,J),
                         ER(24,J),ER(25,J)
   26 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3700)
      WRITE(20,2700)

      DO 27, J=1,24
          WRITE(20,3800) TIME(J),ER(26,J),ER(27,J),ER(28,J),
                         ER(29,J),ER(30,J)
   27 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,2800)
      WRITE(20,2900)
      WRITE(20,2700)

      DO 28, J=1,24
          WRITE(20,3900) TIME(J),CI(2,J),CI(3,J),CI(4,J),CI(5,J),
```

```
     +    CI(6,J),CI(7,J)
   28 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3100)
      WRITE(20,2700)

      DO 29,J=1,24
          WRITE(20,4000) TIME(J),CI(8,J),CI(9,J),CI(10,J),
                         CI(11,J),CI(12,J),CI(15,J)
   29 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3300)
      WRITE(20,2700)

      DO 31,J=1,24
          WRITE(20,4100) TIME(J),CI(16,J),CI(17,J),CI(18,J),
                         CI(19,J),CI(20,J)
   31 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3500)
      WRITE(20,2700)

      DO 32,J=1,24
          WRITE(20,4200) TIME(J),CI(21,J),CI(22,J),CI(23,J),
     +                   CI(24,J),CI(25,J)
   32 CONTINUE

      WRITE(20,*) "1"
      WRITE(20,2700)
      WRITE(20,3700)
      WRITE(20,2700)

      DO 33,J=1,24
          WRITE(20,4300) TIME(J),CI(26,J),CI(27,J),CI(28,J),
     +                   CI(29,J),CI(30,J)
   33 CONTINUE
C *****************************************************************
C     CALCULATE A CURRENT LOCATION FACTOR FOR EACH COUNTRY
C     VALUES WILL BE GIVEN ON A US AND UK BASIS
C     RESULTS CAN BE FOUND IN FILENAME 'TABLE'
C *****************************************************************

      WRITE(17,1000) "1"
      DO 30,I=1,6
          WRITE(17,*) " "
   30 CONTINUE

C.....OUTPUT HEADINGS TO FILE 'TABLE'
```

```
      WRITE(17,1300)
      WRITE(17,1200)
      WRITE(17,1300)
      WRITE(17,*) " "
      SELB=1
   40 WRITE(17,1900)
      WRITE(17,1700)
      WRITE(17,1750)
      WRITE(17,1800)
      WRITE(17,1900)
      WRITE(17,*) " "

C.....CALCULATE (US BASIS) AND OUTPUT VALUES TO FILE

      DO 50 SELC=1,32
          IF (SELB.EQ.1) THEN
             LF=USB(SELC)
             ORIG24=ER(SELC,N)
             ORIG1=ER(SELC,1)
          ELSE
             LF=UKB(SELC)
             ORIG24=ER(SELC,N)/ER(SELB,N)
             ORIG1=ER(SELC,1)/ER(SELB,1)
          ENDIF

          NLF=LF*(CI(SELB,1)/CI(SELB,N))*(CI(SELC,N)/CI(SELC,1))*
     +    ORIG1/ORIG24
          WRITE(17,1600) CNTRY(SELC),LF,ORIG1,NLF,ORIG24
   50 CONTINUE

      WRITE(17,1000) "1"

      IF (SELB.EQ.2) THEN
          GOTO 70
      ENDIF

      DO 60 I=1,5
          WRITE(17,*) " "
   60 CONTINUE

C.....CALCULATE VALUES FOR UK BASIS (REPEAT LOOP)

      WRITE(17,1500)
      WRITE(17,1400)
      WRITE(17,1500)
      WRITE(17,*) " "
      SELB=2
      GOTO 40

C ****************************************************************
C      CALCULATE LOCATION FACTORS FOR A SPECIFIC COUNTRY
C      (BASIS U.K. OR U.S.A.) FOR EACH QUARTER SINCE 1979
C ****************************************************************

C.....LIST COUNTRIES THAT ARE AVAILABLE
```

```
   70 PRINT*,"    SELECT COUNTRY OF INTEREST"
      PRINT
      DO 80 I=1,32
          WRITE(6,2100) I,CNTRY(I)
          IF (I.EQ.16) THEN
              PRINT
              PRINT*,"PRESS RETURN TO CONTINUE"
              PRINT*,"LIST OF COUNTRIES AVAILABLE"
              READ(7,1000) AGAIN
          ENDIF
   80 CONTINUE

      PRINT
 1    PRINT*,"SELECT COUNTRY OF INTEREST BY"
      PRINT*,"TYPING IN THE RELEVENT NUMBER"
      PRINT

      READ(7,*) SELC


      IF(SELC.LT.1.OR.SELC.GT.32) THEN
          PRINT*,"TRY AGAIN!"
          PRINT
          GOTO 1
      ENDIF

C.....SELECT BASE REQUIRED

      PRINT
      PRINT*,"    SELECT BASE"
      PRINT*,"1      U.S.A."
      PRINT*,"2      U.K."

      PRINT
2     READ(7,*) SELB

      IF(SELB.LT.1.OR.SELB.GT.2) THEN
          PRINT*,"TRY AGAIN!"
          GOTO 2
      ENDIF

C ******************************************************************
C     CALCULATE NEW LOCATION FACTORS AND STORE IN FILE
C ******************************************************************

      IF (SELB.EQ.1) THEN
          LF = USB(SELC)
      ELSE
          LF = UKB(SELC)
          DO 90 I=1,N
              ER(SELC,I)=ER(SELC,I)/ER(SELB,I)
   90     CONTINUE
      ENDIF

C.....CALCULATE AND WRITE RESULTS TO FILE
```

```
      WRITE(16,1000) "1"
      WRITE(16,2500)
      WRITE(16,2300)
      WRITE(16,2400) CNTRY(SELC)
      WRITE(16,2500)
      WRITE(16,*) " "


      WRITE(21,2500)
      WRITE(21,4500)
      WRITE(21,4600)
      WRITE(21,2500)
      DO 100 J=1,24
          NLF   =   LF   *   (CI(SELB,1)/CI(SELB,J))   *          +
(CI(SELC,J)/CI(SELC,1))
     +        * (ER(SELC,1)/ER(SELC,J))

          ARRAY(J) = NLF

          LFER(J)=ARRAY(J)*ER(SELC,J)
          WRITE(16,2200) TIME(J),CI(SELB,J),CI(SELC,J),ER(SELC,J)
     +    ,ARRAY(J)
          WRITE(21,4400) TIME(J),ARRAY(J),ER(SELC,J),LFER(J)
  100 CONTINUE

C ******************************************************************
C       CALCULATED VALUES AND DATA WILL BE PLOTTED ON
C       THE SCREEN OR STORED IN A FILE WHICH CAN BE
C       SENT TO THE PLOTTER USING 'UAPLOT'
C ******************************************************************

      XMIN = 1979
      XMAX = 1985

      DO 110 I=1,N
          V(I)=CI(SELC,I)
          W(I)=CI(SELB,I)
          X(I) = TIME(I)
          Y(I) = 1/ER(SELC,I)
          Z(I) = ARRAY(I)
  110 CONTINUE

      K=3
      CALL MINMAX(Z,V,ZMAX,ZMIN,N,K)
      CALL LIMITS(ZMIN,ZMAX,NTS,K)

      K=1
      CALL MINMAX(Y,V,YMAX,YMIN,N,K)
      CALL LIMITS(YMIN,YMAX,NPTS,K)

      K=2
      CALL MINMAX(W,V,WMAX,WMIN,N,K)
      CALL LIMITS(WMIN,WMAX,NOPTS,K)

      K=4
```

```
      CALL MINMAX(LFER,V,LMAX,LMIN,N,K)
      CALL LIMITS(LMIN,LMAX,NOTS,K)

C.....GRAPHS WILL BE DRAWN USING GINO ROUTINES

      WRITE(3,*) 'ENTER 1 FOR SCREEN OR 2 FOR PLOTTER'
      READ(7,*) IDEV
      IF (IDEV.NE.1) THEN
          PRINT*,"INPUT COUNTRY OF INTEREST AND BASE COUNTRY"
          READ(7,2600) (NAME(I),I=1,18)
          PRINT
          PRINT*,"GRAPHS  WILL  BE  STORED  IN FILENAME GRAPHS. TO
+             OUTPUT"
          PRINT*,"FILE  WHEN  PROGRAM COMPLETED,TYPE 'UAPLOT      +
        GRAPHS'"
          PRINT
          CALL OPEN
          CALL DEVPAP(600.,300.,1)
      ELSE
          PRINT
          PRINT*,"ON  COMPLETION  OF  FIRST  GRAPH,PRESS RETURN TO
+            CONTINUE"
          PRINT
          PRINT*,"PRESS RETURN TO CONTINUE"
          READ(7,1000) AGAIN
          CALL T4010
          CALL PICCLE
      END IF

C.....FOR EXPLANATION OF GINO ROUTINES, CONSULT MANUAL

      CALL CHASIZ(2.2,3.)
      CALL LOCAXIS(X,Z,N,NTS,XMIN,XMAX,ZMIN,ZMAX)
      CALL AXIPOS(0,120.,20.,100.,2)
      CALL AXISCA(3,NPTS,YMIN,YMAX,2)
      CALL AXIDRA(1,1,2)
      CALL BROKEN(1)
      CALL PENSEL(5,1.,1.)
      CALL GRAPOL(X,Y,N)
      CALL PENSEL(1,1.,1.)
      CALL BROKEN(0)

C.....TO LABEL AXES

      CALL MOVTO2(60.,5.)
      CALL CHAHOL(12HTIME YEARS*.)

      CALL MOVTO2(5.,50.)
      CALL CHAANG(90.)
      CALL CHAHOL(18HLOCATION FACTORS*.)

      CALL MOVTO2(140.,105.)
      CALL CHAANG(-90.)
      IF (SELB.EQ.1) THEN
          CALL CHAHOL(32HEXCHANGE RATE DOLLARS PER UNIT*.)
```

```
      ELSE
          CALL CHAHOL(31HEXCHANGE RATE POUNDS PER UNIT*.)
      END IF
      CALL CHAANG(0.)

C.....TO ADD LEGEND TO FIRST GRAPH

      CALL MOVTO2(35.,125.)
      CALL PENSEL(2,1.,1.)
      CALL LINBY2(10.,0.)
      CALL PENSEL(1,1.,1.)
      CALL CHAHOL(19H LOCATION FACTORS*.)
      CALL MOVTO2(35.,130.)
      CALL BROKEN(1)
      CALL LINBY2(10.,0.)
      CALL BROKEN(0)
      IF (SELB.EQ.1) THEN
         CALL CHAHOL(33H EXCHANGE RATE DOLLARS PER UNIT*.)
      ELSE
         CALL CHAHOL(32H EXCHANGE RATE POUNDS PER UNIT*.)
      END IF

C     TO SHIFT ORIGIN (PLOTTER) OR CLEAR SCREEN

      IF (IDEV.NE.1) THEN
          CALL SHIFT2(200.,0.)
      ELSE
          READ(7,1000) AGAIN
          CALL PICCLE
      END IF

      CALL LOCAXIS(X,Z,N,NTS,XMIN,XMAX,ZMIN,ZMAX)
      CALL AXIPOS(0,120.,20.,100.,2)
      CALL AXISCA(3,NOPTS,WMIN,WMAX,2)
      CALL AXIDRA(1,1,2)
      CALL PENSEL(7,1.,1.)
      CALL BROKEN(1)
      CALL GRAPOL(X,W,N)
      CALL PENSEL(1,1.,1.)
      CALL BROKEN(0)
      CALL DASHED(2,2.,1.2,0.2)
      CALL GRAPOL(X,V,N)
      CALL DASHED(0,2.,1.,1.)

C.....LABEL AXES

      CALL MOVTO2(60.,5.)
      CALL CHAHOL(12HTIME YEARS*.)

      CALL MOVTO2(5.,50.)
      CALL CHAANG(90.)
      CALL CHAHOL(18HLOCATION FACTORS*.)

      CALL MOVTO2(140.,90.)
      CALL CHAANG(-90.)
```

```
      CALL CHAHOL(14HCOST INDICES*.)
      CALL CHAANG(0.)

C.....ADD LEGEND TO TOP OF GRAPH

      CALL MOVTO2(40.,125.)
      CALL PENSEL(2,1.,1.)
      CALL LINBY2(10.,0.)
      CALL PENSEL(1,1.,1.)
      CALL CHAHOL(19H LOCATION FACTORS*.)
      CALL MOVTO2(40.,130.)
      CALL BROKEN(1)
      CALL PENSEL(7,1.,1.)
      CALL LINBY2(10.,0.)
      CALL PENSEL(1,1.,1.)
      CALL CHAHOL(18H BASE COST INDEX*.)
      CALL MOVTO2(40.,135.)
      CALL DASHED(2,2.,1.2,0.2)
      CALL LINBY2(10.,0.)
      CALL CHAHOL(30H INDEX OF INTERESTED COUNTRY*.)
      CALL DASHED(2,2.,2.,0.)

      IF (IDEV.NE.1) THEN
          CALL SHIFT2(200.,0.)
      ELSE
          READ(7,1000) AGAIN
          CALL PICCLE
      END IF
C.....PLOT  GRAPH  OF  LOCATION FACTOR TIMES EXCHANGE RATE AGAINST
  TIME


      CALL LOCAXIS(X,LFER,N,NOTS,XMIN,XMAX,LMIN,LMAX)
      CALL MOVTO2(60.,5.)
      CALL CHAHOL(12HTIME YEARS*.)

      CALL MOVTO2(5.,30.)
      CALL CHAANG(90.)
      CALL CHAHOL(37HLOCATION FACTOR TIMES EXCHANGE RATE*.)
      CALL CHAANG(-0.)
C.....TITLE GRAPHS FOR PLOTTER

      IF (IDEV.NE.1) THEN
          CALL CHASIZ(2.5,3.5)
          CALL MOVTO2(-185.,150.)
          CALL  CHAHOL(46HLOCATION  FACTOR AND COST  INDICES VERSUS
  +                 TIME*.)
          CALL MOVTO2(-385.,150.)
         CALL  CHAHOL(47HLOCATION  FACTOR AND EXCHANGE RATE VERSUS
  +                TIME*.)
          CALL MOVTO2(-385.,141.)
          CALL CHAA1(NAME,18)
      ENDIF
      CALL DEVEND
      STOP
```

```
C.....FORMAT STATEMENTS USED TO CONTROL STYLE OF OUTPUT

 1000 FORMAT(A1)
 1100 FORMAT(A11,6X,F4.2,3X,F4.2)
 1200 FORMAT(37X,"BASE U.S.A.")
 1300 FORMAT(37X,11("*"))
 1400 FORMAT(37X,"BASE U.K.")
 1500 FORMAT(37X,9("*"))
 1600 FORMAT(1X,A11,7X,F4.2,8X,F9.4,7X,F6.4,8X,F9.4)
 1700 FORMAT(17X,'ORIGINAL',7X,'ORIGINAL',8X,'UPDATED',
     +        9X,'CURRENT')
 1750 FORMAT(2X,'COUNTRY',4X,'LOCATION FACTOR',1X,'AT',1X,
     +        'EXCHANGE',5X,
     +        'LOCATION FACTOR',1X,'AT',1X,'EXCHANGE')
 1800   FORMAT(13X,'1st  QUARTER  1979',5X,'RATE',7X,'4th  QUARTER
+1984',5X,'RATE')
 1900 FORMAT(1X,71("*"))
 2100 FORMAT(I3,7X,A10)
 2200 FORMAT(1X,F7.2,7X,F6.2,7X,F6.2,7X,F9.5,7X,F6.4)
 2300             FORMAT(2X,"YEAR",8X,"COST             INDEX",3X,"COST
+INDEX",5X,"EXCHANGE",6X,"CALCULATED")
 2400 FORMAT(16X,"BASE",7X,A11,6X,"RATE",6X,"LOCATION FACTOR")
 2500 FORMAT(1X,68("*"))
 2600 FORMAT(18A1)
 2700 FORMAT(1X,66("*"))
 2800 FORMAT(2X,'YEAR',6X,'UNITED',3X,'BELGIUM',3X,'DENMARK',3X,
     +'FRANCE',4X,'WEST',5X,'GREECE')
 2900 FORMAT(11X,'KINGDOM',32X,'GERMANY')
 3000 FORMAT(1X,F7.2,4X,F6.4,3X,F6.3,4X,F7.4,3X,F6.4,4X,F6.4,
     +3X,F6.2)
 3100 FORMAT(2X,'YEAR',6X,'ITALY',3X,'HOLLAND',3X,'NORWAY',3X,
     +'SPAIN',3X,'SWEDEN',3X,'YUGOSLAVIA')
 3200 FORMAT(1X,F7.2,4X,F6.1,3X,F6.4,3X,F6.4,2X,F6.2,3X,F6.4,
     +4X,F7.3)
 3300 FORMAT(2X,'YEAR',6X,'CANADA',5X,'BRAZIL',5X,'MEXICO',5X,
     +        'VENEZUELA',5X,'S.AFRICA')
 3400 FORMAT(1X,F7.2,4X,F6.4,6X,F6.2,4X,F6.2,7X,F6.4,7X,F6.4)
 3500 FORMAT(2X,'YEAR',7X,'TUNISIA',5X,'ZAMBIA',5X,'EGYPT',
     +        5X,'ISRAEL',5X,'TURKEY')
 3600 FORMAT(1X,F7.2,6X,F6.4,5X,F6.4,5X,F6.4,4X,F6.2,5X,F6.2)
 3700 FORMAT(2X,'YEAR',6X,'AUSTRALIA',5X,'INDONESIA',5X,'JAPAN',
     +        4X,'KOREA',4X,'PHILLIPINES')
 3800 FORMAT(1X,F7.2,6X,F6.4,6X,F7.2,6X,F6.2,4X,F6.2,4X,F7.4)
 3900 FORMAT(1X,F7.2,5X,F4.0,6X,F4.0,6X,F4.0,5X,F4.0,5X,F4.0,
     +6X,F4.0)
  4000 FORMAT(1X,F7.2,5X,F4.0,4X,F5.0,6X,F4.0,4X,F4.0,5X,F4.0,
     +        6X,F4.0)
 4100 FORMAT(1X,F7.2,5X,F4.0,6X,F6.0,6X,F5.0,7X,F5.0,9X,F4.0)
 4200 FORMAT(1X,F7.2,7X,F4.0,7X,F4.0,7X,F4.0,6X,F6.0,6X,F5.0)
 4300 FORMAT(1X,F7.2,7X,F4.0,10X,F4.0,8X,F4.0,5X,F4.0,8X,F4.0)
 4400 FORMAT(1X,F7.2,7X,F6.4,7X,F9.5,7X,F9.4)
 4500 FORMAT(1X,'YEAR',4X,'LOCATION',4X,'EXCHANGE',4X,'L.F.*ER')
 4600 FORMAT(9X,'FACTOR,L.F.',6X,'RATE,ER')
      END
```

```
      SUBROUTINE LIMITS(YMIN,YMAX,NOPTS,K)

C ****************************************************************
C     SUBROUTINE LIMITS ENABLES THE USER TO CONTROL
C     THE SCALING OF THE AXES WHEN PLOTTING EXCHANGE
C     RATES,COST INDICES AND LOCATION FACTORS.
C ****************************************************************


      IF (K.EQ.1) THEN
          PRINT*,"TO SCALE THE EXCHANGE RATE AXIS"
      ELSEIF (K.EQ.2) THEN
          PRINT*,"TO SCALE THE COST INDEX AXIS"
      ELSEIF (K.EQ.3)
          PRINT*,"TO SCALE LOCATION FACTOR AXIS"
      ELSE
          PRINT*,"TO SCALE 'CONSTANT' AXIS"
      ENDIF

      PRINT
      PRINT*,"CURRENT MINIMUM AND MAXIMUM VALUES ARE",YMIN,YMAX
      PRINT*,"PLEASE  TYPE  IN  VALUES  REQUIRED  (WHOLE  NUMBERS
+PREFERRED)"
      READ*,YMIN,YMAX
      PRINT
      PRINT*,"INPUT NUMBER OF INTERVALS REQUIRED"
      READ*,NOPTS
      PRINT
      IF (K.EQ.4) THEN
          PRINT*,"THANK-YOU"
          PRINT
      ENDIF

      RETURN

      END
```

```
      SUBROUTINE LOCAXIS(X,Z,N,NTS,XMIN,XMAX,ZMIN,ZMAX)

C.....TO PLOT LOCATION FACTOR AND TIME AXES

      CALL AXIPOS(0,20.,20.,100.,2)
      CALL AXIPOS(0,20.,20.,100.,1)
      CALL AXISCA(3,6,XMIN,XMAX,1)
      CALL AXISCA(3,NTS,ZMIN,ZMAX,2)
      CALL AXIDRA(1,1,1)
      CALL AXIDRA(-1,-1,2)
      CALL PENSEL(2,1.,1.)
      CALL GRAPOL(X,Z,N)
      CALL PENSEL(1,1.,1.)

      RETURN

      END
```

```
      SUBROUTINE MINMAX(U,V,MAX,MIN,N,K)

C.....TO CALCULATE THE MINIMUM AND MAXIMUM VALUES OF DATA

      REAL U(35),V(35),MIN,MAX

      SORT=U(1)
      DO 120, I=1,N
           IF (SORT.LT.U(I)) THEN
                SORT=U(I)
           ENDIF
           IF (K.EQ.2) THEN
                IF (SORT.LT.V(I)) THEN
                     SORT=V(I)
                ENDIF
           ENDIF
120   CONTINUE
      MAX=SORT

      DO 130, I=1,N
           IF (SORT.GT.U(I)) THEN
                SORT=U(I)
           ENDIF
           IF (K.EQ.2) THEN
                IF (SORT.GT.V(I)) THEN
                     SORT=V(I)
                ENDIF
           ENDIF
130   CONTINUE
      MIN=SORT

      RETURN

      END
```

APPENDIX D DATA USED BY THE PROGRAM

Table D1 Quarterly exchange rates per Dollar for each country

YEAR	UNITED KINGDOM	BELGIUM	DENMARK	FRANCE	WEST GERMANY	GREECE
1979.00	0.4961	29.294	5.1158	4.2680	1.8548	36.49
1979.25	0.4807	30.272	5.3635	3.3743	1.8947	37.18
1979.50	0.4480	29.227	5.2360	4.2343	1.8162	36.77
1979.75	0.4632	28.602	5.2885	4.1412	1.7660	37.72
1980.00	0.4437	28.782	5.5362	4.1491	1.7734	39.30
1980.25	0.4377	29.005	5.6398	4.2121	1.1805	42.97
1980.50	0.4200	28.439	5.4942	4.1491	1.7756	43.17
1980.75	0.4192	30.695	5.8736	4.4215	1.9112	45.03
1981.00	0.4329	33.801	6.4714	4.8598	2.0866	49.95
1981.25	0.4865	37.184	7.1497	5.4185	2.2758	55.48
1981.50	0.5445	39.789	7.6351	5.8084	2.4327	59.56
1981.75	0.5309	37.741	7.2369	5.6516	2.2448	56.64
1982.00	0.5414	41.480	7.7706	5.9949	2.3459	60.55
1982.25	0.5618	45.010	8.1096	6.2799	2.3780	64.72
1982.50	0.5796	47.554	8.6514	6.9418	2.4812	70.15
1982.75	0.6062	48.718	8.7982	7.0731	2.5012	71.79
1983.00	0.6526	47.432	8.5334	6.8874	2.4078	83.27
1983.25	0.6429	49.616	8.8611	7.4700	2.4848	84.18
1983.50	0.6622	53.075	9.5066	7.9601	2.6429	88.56
1983.75	0.6802	54.493	9.6789	8.1677	2.6776	95.95
1984.00	0.7266	56.110	10.1465	8.8325	2.7770	108.47
1984.25	0.7159	55.280	9.9560	8.3317	2.7095	107.28
1984.50	0.8084	59.007	10.6313	8.9602	2.9189	115.90
1984.75	0.8050	60.374	10.8010	9.1741	2.9886	123.29

YEAR	ITALY	HOLLAND	NORWAY	SPAIN	SWEDEN	YUGOSLAVIA
1979.00	839.1	2.0030	5.0857	69.38	4.3578	18.667
1979.25	847.0	2.0642	5.1625	66.71	4.3746	19.095
1979.50	816.7	1.9973	5.0186	66.06	4.2105	19.089
1979.75	820.6	1.9595	4.9894	66.35	4.2053	19.134
1980.00	824.8	1.9533	4.9486	67.29	4.2182	20.085
1980.25	851.5	1.9904	4.9425	70.82	4.2481	23.070
1980.50	843.4	1.9355	4.8412	72.10	4.1518	27.580
1980.75	906.7	2.0733	5.0250	76.61	4.3002	28.910
1981.00	1001.4	2.2838	5.3501	84.09	4.5539	30.183
1981.25	1134.1	2.5265	5.6836	91.14	4.8769	33.134
1981.50	1215.4	2.7031	6.0852	97.97	5.3018	37.603
1981.75	1196.2	2.4675	5.8391	96.06	5.5211	38.946
1982.00	1261.8	2.5759	5.9531	101.22	5.7362	44.327
1982.25	1319.3	2.6377	6.0771	106.02	5.9002	46.177
1982.50	1393.6	2.7296	6.6416	112.17	6.1569	49.865
1982.75	1435.2	2.7376	7.1461	120.02	7.3371	60.734
1983.00	1399.4	2.6631	7.1099	129.91	7.4094	70.091
1983.25	1477.5	2.7928	7.1697	138.95	7.5369	82.689
1983.50	1573.7	2.9570	7.4032	150.26	7.8060	99.353
1983.75	1624.8	3.0036	7.5026	154.59	7.9162	119.221
1984.00	1712.4	3.1298	7.9320	157.50	8.1279	139.665
1984.25	1675.4	3.0508	7.7411	152.91	8.0022	134.001
1984.50	1799.5	3.2931	8.3661	165.19	8.4073	159.655
1984.75	1859.4	3.3742	8.7043	167.78	8.5827	195.374

YEAR	CANADA	BRAZIL	MEXICO	VENEZUELA	S.AFRICA
1979.00	1.1864	21.94	22.76	4.2925	0.8562
1979.25	1.1581	24.55	22.83	4.2925	0.8459
1979.50	1.1633	27.30	22.81	4.2925	0.8377
1979.75	1.1747	33.99	22.83	4.2925	0.8282
1980.00	1.1643	45.01	22.82	4.2925	0.8141
1980.25	1.1703	50.10	22.85	4.2925	0.7091
1980.50	1.1586	54.70	23.00	4.2925	0.7592
1980.75	1.1839	61.33	23.13	4.2925	0.7510
1981.00	1.1936	70.08	23.49	4.2925	0.7698
1981.25	1.1986	83.89	24.09	4.2925	0.8371
1981.50	1.2117	99.72	24.79	4.2925	0.9396
1981.75	1.1918	118.08	25.68	4.2925	0.9624
1982.00	1.2089	137.87	34.34	4.2925	0.9952
1982.25	1.2445	160.18	46.77	4.2925	1.0760
1982.50	1.2498	189.65	71.18	4.2925	1.1493
1982.75	1.2315	230.36	73.32	4.2925	1.1273
1983.00	1.2273	324.43	102.02	4.2925	1.0835
1983.25	1.2310	475.89	114.20	4.2974	1.0885
1983.50	1.2328	683.36	126.12	4.3000	1.1074
1983.75	1.2385	867.50	138.04	4.3000	1.1740
1984.00	1.2873	886.60	161.85	7.5000	1.3447
1984.25	1.2927	514.42	161.88	7.5000	1.2754
1984.50	1.3139	671.42	173.73	7.5000	1.5719
1984.75	1.3163	800.00	185.67	7.5000	1.7966

YEAR	TUNISIA	ZAMBIA	EGYPT	ISRAEL	TURKEY
1979.00	0.4074	0.7957	1.4286	1.96	25.25
1979.25	0.4119	0.8017	1.4286	2.34	28.36
1979.50	0.4055	0.7842	1.4286	2.68	35.35
1979.75	0.4010	0.7878	1.4286	3.19	35.35
1980.00	0.4010	0.7928	1.4286	3.84	61.60
1980.25	0.4048	0.7820	1.4286	4.51	75.54
1980.50	0.4006	0.7804	1.4286	5.41	80.10
1980.75	0.4134	0.7900	1.4286	6.73	86.93
1981.00	0.4327	0.8228	1.4286	8.41	94.95
1981.25	0.4996	0.8649	1.4286	10.27	102.84
1981.50	0.5288	0.9096	1.4286	12.54	118.89
1981.75	0.5141	0.8832	1.4286	14.50	128.56
1982.00	0.5377	0.9014	1.4286	17.45	142.25
1982.25	0.5273	0.9177	1.4286	21.28	153.27
1982.50	0.6215	0.9433	1.4286	26.96	171.86
1982.75	0.6314	0.9522	1.4286	31.26	182.84
1983.00	0.6303	1.1561	1.4286	36.67	194.15
1983.25	0.6683	1.1874	1.4286	43.39	212.15
1983.50	0.7018	1.2827	1.4286	55.54	235.02
1983.75	0.7137	1.4049	1.4286	89.25	260.51
1984.00	0.7332	1.7172	1.4286	211.39	348.38
1984.25	0.7381	1.6939	1.4286	192.31	347.92
1984.50	0.7829	1.8726	1.4286	311.21	387.27
1984.75	0.8410	2.0538	1.4286	550.28	429.49

YEAR	AUSTRALIA	INDONESIA	JAPAN	KOREA	PHILLIPINES
1979.00	0.8795	614.32	201.46	484.00	7.3769
1979.25	0.9019	625.38	217.62	484.00	7.3773
1979.50	0.8868	625.59	218.86	484.00	7.3715
1979.75	0.9062	626.94	238.62	484.00	7.3846
1980.00	0.9079	627.79	243.54	582.27	7.4202
1980.25	0.8890	627.20	232.84	596.57	7.5158
1980.50	0.8607	625.74	220.05	613.33	7.5632
1980.75	0.8550	626.68	210.67	652.12	7.5805
1981.00	0.8559	628.30	205.57	667.17	7.6770
1981.25	0.8737	629.70	220.00	680.95	7.8590
1981.50	0.8748	633.10	231.89	685.89	7.9640
1981.75	0.8761	635.90	224.68	690.10	8.0990
1982.00	0.9201	647.30	233.49	710.07	8.2930
1982.25	0.9450	653.60	244.15	728.17	8.4150
1982.50	1.0169	662.90	258.86	741.60	8.5520
1982.75	1.0514	681.90	259.68	744.69	8.9000
1983.00	1.0584	698.20	235.74	753.43	9.4520
1983.25	1.1436	969.70	237.55	769.54	10.0950
1983.50	1.1350	981.30	242.53	785.25	11.0020
1983.75	1.0983	987.90	234.25	794.78	13.9020
1984.00	1.1225	1013.20	234.69	801.47	15.7130
1984.25	1.1026	1006.50	229.61	798.17	15.1350
1984.50	1.1933	1038.36	243.46	810.52	18.0020
1984.75	1.1636	1063.20	243.32	816.59	19.9590

Table D2 Quarterly plant cost indexes for each country based on the Process Economics International Journal

YEAR	UNITED KINGDOM	BELGIUM	DENMARK	FRANCE	WEST GERMANY	GREECE
1979.00	173.	137.	168.	158.	117.	206.
1979.25	176.	137.	169.	162.	120.	219.
1979.50	180.	137.	171.	166.	121.	228.
1979.75	189.	138.	165.	172.	123.	242.
1980.00	197.	140.	169.	178.	123.	266.
1980.25	201.	144.	174.	185.	129.	280.
1980.50	203.	145.	176.	189.	130.	292.
1980.75	207.	147.	181.	193.	130.	296.
1981.00	212.	148.	176.	197.	133.	324.
1981.25	215.	150.	183.	206.	135.	344.
1981.50	217.	153.	188.	214.	137.	361.
1981.75	220.	154.	192.	225.	140.	375.
1982.00	225.	164.	194.	240.	143.	400.
1982.25	232.	168.	197.	251.	147.	425.
1982.50	233.	172.	201.	256.	148.	450.
1982.75	237.	176.	207.	260.	148.	472.
1983.00	240.	172.	208.	255.	142.	480.
1983.25	242.	174.	212.	263.	145.	498.
1983.50	246.	176.	215.	268.	147.	517.
1983.75	251.	179.	219.	274.	147.	547.
1984.00	255.	182.	223.	281.	148.	565.
1984.25	260.	185.	227.	287.	149.	585.
1984.50	266.	188.	230.	295.	150.	610.
1984.75	271.	190.	233.	302.	151.	625.

YEAR	ITALY	HOLLAND	NORWAY	SPAIN	SWEDEN	YUGOSLAVIA
1979.00	182.	122.	143.	210.	141.	168.
1979.25	190.	124.	144.	229.	148.	173.
1979.50	205.	124.	148.	232.	149.	179.
1979.75	211.	127.	145.	247.	152.	190.
1980.00	223.	127.	148.	254.	156.	197.
1980.25	233.	129.	153.	272.	158.	212.
1980.50	243.	129.	162.	285.	161.	223.
1980.75	252.	132.	158.	300.	167.	225.
1981.00	266.	133.	164.	320.	170.	242.
1981.25	280.	134.	166.	340.	172.	258.
1981.50	296.	137.	173.	349.	172.	272.
1981.75	305.	137.	173.	352.	177.	287.
1982.00	319.	142.	176.	374.	188.	297.
1982.25	330.	145.	180.	390.	190.	312.
1982.50	346.	145.	184.	395.	190.	328.
1982.75	363.	146.	188.	400.	192.	344.
1983.00	373.	148.	190.	420.	200.	355.
1983.25	382.	148.	194.	439.	206.	375.
1983.50	393.	148.	197.	456.	206.	407.
1983.75	405.	149.	201.	464.	210.	450.
1984.00	419.	152.	205.	470.	215.	480.
1984.25	430.	154.	209.	490.	219.	510.
1984.50	442.	156.	213.	510.	222.	540.
1984.75	454.	158.	217.	530.	227.	570.

YEAR	CANADA	BRAZIL	MEXICO	VENEZUELA	S.AFRICA
1979.00	149.	364.	219.	159.	172.
1979.25	154.	405.	227.	162.	172.
1979.50	158.	468.	232.	166.	190.
1979.75	162.	563.	245.	176.	192.
1980.00	165.	669.	264.	184.	193.
1980.25	170.	804.	275.	187.	194.
1980.50	174.	993.	294.	193.	220.
1980.75	178.	1109.	296.	197.	223.
1981.00	184.	1426.	318.	188.	226.
1981.25	189.	1706.	355.	212.	237.
1981.50	192.	2017.	371.	220.	248.
1981.75	197.	2359.	394.	220.	260.
1982.00	202.	2805.	431.	228.	288.
1982.25	206.	3374.	554.	231.	294.
1982.50	207.	4090.	619.	235.	321.
1982.75	211.	4758.	712.	235.	328.
1983.00	213.	5761.	859.	240.	334.
1983.25	213.	7117.	1019.	246.	345.
1983.50	215.	8472.	1146.	252.	357.
1983.75	217.	10097.	1289.	257.	370.
1984.00	220.	12026.	1449.	264.	380.
1984.25	223.	14324.	1630.	271.	390.
1984.50	226.	17061.	1833.	279.	400.
1984.75	229.	20325.	2062.	287.	410.

YEAR	TUNISIA	ZAMBIA	EGYPT	ISRAEL	TURKEY
1979.00	112.	209.	147.	389.	335.
1979.25	115.	217.	148.	574.	437.
1979.50	119.	229.	151.	671.	501.
1979.75	121.	240.	160.	831.	596.
1980.00	124.	248.	138.	1003.	883.
1980.25	127.	258.	167.	1273.	988.
1980.50	130.	269.	160.	1587.	1020.
1980.75	131.	281.	160.	1756.	1106.
1981.00	139.	205.	168.	2562.	941.
1981.25	141.	209.	172.	3199.	987.
1981.50	145.	213.	175.	3711.	1034.
1981.75	153.	218.	177.	4455.	1078.
1982.00	163.	252.	182.	5531.	1186.
1982.25	166.	253.	185.	6793.	1260.
1982.50	171.	258.	191.	8497.	1293.
1982.75	175.	260.	194.	16725.	1344.
1983.00	176.	293.	201.	13432.	1481.
1983.25	180.	312.	203.	16489.	1585.
1983.50	183.	334.	204.	20713.	1696.
1983.75	184.	357.	206.	27789.	1868.
1984.00	184.	381.	208.	37282.	2143.
1984.25	185.	407.	210.	50019.	2458.
1984.50	186.	434.	212.	67109.	2828.
1984.75	187.	450.	214.	90030.	3236.

YEAR	AUSTRALIA	INDONESIA	JAPAN	KOREA	PHILLIPINES	U.S.
1979.00	157.	211.	134.	267.	143.	132.
1979.25	157.	235.	134.	283.	152.	133.
1979.50	163.	264.	137.	310.	163.	140.
1979.75	165.	275.	137.	340.	169.	143.
1980.00	173.	300.	140.	440.	210.	157.
1980.25	174.	321.	146.	485.	217.	153.
1980.50	176.	331.	148.	483.	202.	157.
1980.75	199.	335.	148.	524.	212.	155.
1981.00	184.	410.	151.	347.	192.	161.
1981.25	188.	410.	153.	380.	197.	166.
1981.50	191.	411.	155.	412.	203.	168.
1981.75	196.	412.	157.	425.	210.	172.
1982.00	203.	421.	158.	407.	217.	175.
1982.25	209.	424.	159.	427.	222.	177.
1982.50	215.	429.	161.	465.	229.	178.
1982.75	220.	433.	162.	479.	232.	179.
1983.00	225.	439.	162.	453.	231.	180.
1983.25	230.	536.	163.	480.	235.	181.
1983.50	235.	548.	165.	510.	149.	185.
1983.75	240.	555.	166.	520.	297.	187.
1984.00	245.	562.	168.	530.	354.	187.
1984.25	250.	569.	170.	540.	422.	187.
1984.50	255.	576.	172.	550.	503.	188.
1984.75	260.	583.	174.	560.	601.	189.

TABLE D3 Original location factors published in 1979 by Bridgwater [1]

COUNTRY	1979 LOCATION FACTORS - TWO BASES UNITED STATES	UNITED KINGDOM
US	1.00	1.10
UK	0.90	1.00
BELGIUM	1.00	1.10
DENMARK	1.00	1.10
FRANCE	0.95	1.05
GERMANY	1.00	1.10
GREECE	0.90	1.00
ITALY	0.90	1.00
NETHERLANDS	1.00	1.10
NORWAY	1.10	1.20
SPAIN	1.20	1.30
SWEDEN	1.10	1.20
YUGOSLAVIA	0.90	1.00
CANADA	1.15	1.25
BRAZIL	1.30	1.40
MEXICO	0.90	1.00
VENEZUELA	1.20	1.30
AFRICA(S)	1.10	1.20
TUNISIA	1.60	1.75
ZAMBIA	1.80	2.00
EGYPT	1.20	1.30
ISRAEL	1.10	1.20
TURKEY	1.00	1.10
AUSTRALIA	1.30	1.40
INDONESIA	0.90	1.00
JAPAN	0.90	1.00
KOREA	0.80	0.90
PHILIPPINES	0.80	0.90

APPENDIX E TABULATED DATA PRESENTED GRAPHICALLY IN THE THESIS

Table E1 Cost indexes for the United Kingdom (Figure 4.2)

YEAR	RETAIL PRICE INDEX	PROCESS ENGINEERING	PROCESS ECON. INTERNATIONAL	MAN.PRICE INDEX
1972.00	47.8	63.0	61.2	68.2
1972.25	48.0	63.2	62.9	69.4
1972.50	49.5	64.5	63.8	69.5
1972.75	52.3	64.9	64.4	72.3
1973.00	57.0	65.8	65.5	73.6
1973.25	60.3	68.9	68.5	75.9
1973.50	68.3	71.1	70.4	77.0
1973.75	75.8	74.3	73.7	79.7
1974.00	96.2	77.3	76.9	83.0
1974.25	96.7	83.2	81.5	88.0
1974.50	96.3	86.8	86.4	90.2
1974.75	100.0	95.0	94.5	94.3
1975.00	100.0	100.0	100.0	100.0
1975.25	102.1	109.4	108.0	109.4
1975.50	108.3	113.7	112.0	114.1
1975.75	115.9	119.4	117.0	118.1
1976.00	120.6	122.3	120.0	122.4
1976.25	132.4	132.3	131.0	126.8
1976.50	138.8	135.0	135.0	129.8
1976.75	149.3	136.1	139.0	135.8
1977.00	153.4	138.2	139.0	142.6
1977.25	157.6	143.0	140.0	148.9
1977.50	155.2	146.2	141.0	151.2
1977.75	150.6	148.4	143.0	153.4
1978.00	148.5	149.8	147.0	156.1
1978.25	155.0	156.7	164.0	160.4
1978.50	153.5	161.5	165.0	163.1
1978.75	155.8	165.4	169.0	165.9
1979.00	162.5	162.6	173.0	171.1
1979.25	173.0	173.2	176.0	177.4
1979.50	180.0	174.5	180.0	189.2
1979.75	194.8	186.1	189.0	194.5
1980.00	208.9	195.5	197.0	203.8
1980.25	213.2	203.5	201.0	215.6
1980.50	213.9	207.4	203.0	220.1
1980.75	215.4	210.8	207.0	224.3

Table E1 continued

YEAR	RETAIL PRICE INDEX	PROCESS ENGINEERING	PROCESS ECON. INTERNATIONAL	MAN.PRICE INDEX
1981.00	231.5	214.3	212.0	230.4
1981.25	239.2	219.3	215.0	240.7
1981.50	244.6	223.3	217.0	244.9
1981.75	255.0	228.6	220.0	251.0
1982.00	262.1	231.9	225.0	255.1
1982.25	257.4	237.6	232.0	263.2
1982.50	256.4	239.5	233.0	264.5
1982.75	256.4	240.6	237.0	266.4
1983.00	276.8	249.7	240.0	267.8
1983.25	274.6	258.0	242.0	273.3
1983.50	277.2	263.3	246.0	276.7
1983.75	285.2	262.5	251.0	279.8
1984.00	296.8	272.1	255.0	281.6
1984.25	298.3	276.8	260.0	287.3
1984.50	297.9	280.9	266.0	289.8
1984.75	312.6	293.1	271.0	293.4

Table E2 Cost indexes for the United States (Figure 4.1)

YEAR	ENGINEERING NEWS RECORD	CHEMICAL ENGINEERING	MARSHALL & SWIFT	PROCESS ECON. INTERNATIONAL
1970.00	62.	65.	70.	68.
1970.25	64.	69.	70.	69.
1970.50	67.	70.	71.	70.
1970.75	69.	71.	72.	71.
1971.00	70.	72.	72.	72.
1971.25	74.	73.	73.	73.
1971.50	78.	75.	74.	75.
1971.75	79.	75.	74.	75.
1972.00	80.	76.	75.	76.
1972.25	82.	76.	76.	76.
1972.50	85.	76.	76.	76.
1972.75	86.	77.	77.	77.
1973.00	88.	78.	78.	78.
1973.25	90.	79.	78.	79.
1973.50	91.	81.	79.	81.
1973.75	92.	82.	80.	82.
1974.00	92.	84.	83.	85.
1974.25	94.	89.	88.	90.
1974.50	98.	96.	95.	98.
1974.75	100.	99.	99.	99.
1975.00	100.	100.	100.	100.
1975.25	103.	101.	102.	96.
1975.50	108.	101.	103.	97.
1975.75	109.	103.	103.	98.
1976.00	110.	104.	105.	100.
1976.25	113.	106.	107.	101.
1976.50	116.	108.	109.	104.
1976.75	118.	109.	111.	108.
1977.00	119.	111.	112.	109.
1977.25	120.	112.	114.	112.
1977.50	124.	115.	117.	114.
1977.75	127.	117.	119.	116.
1978.00	127.	118.	121.	119.
1978.25	130.	119.	124.	122.
1978.50	135.	119.	129.	124.
1978.75	136.	125.	128.	128.
1979.00	137.	129.	132.	132.
1979.25	140.	131.	136.	133.
1979.50	145.	134.	139.	140.
1979.75	149.	137.	142.	140.
1980.00	149.	138.	147.	151.

Table E2 continued

YEAR	ENGINEERING NEWS RECORD	CHEMICAL ENGINEERING	MARSHALL & SWIFT	PROCESS ECON. INTERNATIONAL
1980.25	149.	143.	149.	153.
1980.50	153.	147.	151.	157.
1980.75	157.	150.	157.	155.
1981.00	160.	155.	154.	161.
1981.25	166.	163.	159.	166.
1981.50	172.	169.	163.	168.
1981.75	175.	170.	163.	172.
1982.00	177.	172.	164.	175.
1982.25	179.	174.	165.	177.
1982.50	185.	174.	166.	178.
1982.75	186.	175.	166.	179.
1983.00	190.	175.	166.	180.
1983.25	193.	175.	168.	181.
1983.50	196.	176.	169.	185.
1983.75	196.	176.	170.	187.
1984.00	196.	177.	171.	187.
1984.25		178.	173.	187.
1984.50		179.	174.	188.
1984.75		179.	174.	189.

Table E3 <u>Exchange rate - Dollars per pound sterling (Figure 6.13)</u>

YEAR	EXCHANGE RATE
1972.75	2.3481
1973.75	2.3232
1974.75	2.3485
1975.75	2.0235
1976.00	1.7024
1976.25	1.7201
1976.50	1.7202
1976.75	1.7465
1977.00	1.9060
1977.25	1.8563
1977.50	1.8602
1977.75	1.9710
1978.00	2.0345
1978.25	2.0259
1978.50	2.0803
1978.75	2.2321
1979.00	2.1589
1979.25	2.2538
1979.50	2.2847
1979.75	2.3809
1980.00	2.3855
1980.25	2.3100
1980.50	2.0555
1980.75	1.8365
1981.00	1.8836
1981.25	1.8470
1981.50	1.7799
1981.75	1.7253
1982.00	1.6496
1982.25	1.5239
1982.50	1.5554
1982.75	1.5101
1983.00	1.4702
1983.25	1.3763
1983.50	1.3968
1983.75	1.2370
1984.00	1.2422

REFERENCES

[1] Bridgwater,A.V.,"International Construction Cost Location Factors",Chemical Engineering, p.119-121, Nov 5th, 1979.

[2] Miller,C.A.,"Converting costs from one country to another", Chemical Engineering, p 89-93, July 2, 1979.

[3] Ohlrichs,P.J.,"Location Cost Factors",Transactions 5th International Cost Engineering Congress, Utrecht, 1978.

[4] Wagialla, K.M., "The use of Location Factors in estimating the total fixed investment of a chemical plant", Process Economics International, vol 5, (1):37-41, 1984.

[5] Alonso, J.P.F., "Estimating the cost of gas cleaning plants", Chemical Engineering, vol 78, p 86-93, Dec 13, 1971.

[6] Peters, M.S., and Timmerhaus, K.D., "Plant Design and Economics for Chemical Engineers", 3rd Ed., McGraw-Hill, 1980.

[7] Aries, R.S. and Newton, R.D., "Chemical Engineering Cost Estimating", McGraw-Hill, 1955.

[8] Berk, J.M. and Haselbarth, J.E., Chemical Engineering, Cost File No.31, vol 67, (10): 158, 1960

[9] Arnold, T.H. and Chilton, C.H., Chemical Engineering, Cost File 81, p 121, Sept 30, 1963.

[10] Bauman, H.C., "Fundamentals of Cost Engineering in the Chemical Industry", Reinhold Publishing Corp., New York, 1964

[11] Jelen, F.C., "Cost and Optimisation Engineering", McGraw-Hill, New York, 1970.

[12] Perry, J.H. and Chilton, C.H., "Chemical Engineering Handbook", 5th and 6th Ed., McGraw-Hill.

[13] Happel, J., "Chemical Process Economics", John Wiley and Sons, 1958.

[14] Roberson, C., "Location Factors", Cost Engineering, vol 18, (1): 15-16, 1979.

[15] Massa, R.V., "International Cost Location Factors", Cost Engineering, vol 25, (5): 15-21, Oct 1983.
Also 1984 A.A.C.E. Transactions, Montreal.

[16] Nelson, W.L., "Effect of location on refinery costs", Oil and Gas Journal, Aug 20, 1973.

[17] Wallace, D.M., "Saudi Arabia building costs", Hydrocarbon Processing, p 189-96, Nov 1976.

[18] Gallagher, J.T., "Efficient estimating of worldwide plant costs", Chemical Engineering, p 196-202, June 2, 1969.

[19] Kharbanda, O.P.

(a) "The Location Factor - the latest view", Cost Engineering, vol 22, (1): 4-6, 1984.

(b) "Location Cost Index - Process Plant", Cost Engineering, vol 19, (4,5,6): 23-7, 1981.

(c) "Process Plant and Equipment Cost Estimation", Chemical Weekly - a special supplement, Sevak Publ., Bombay, 1977.

[20] Bridgwater, A.V., Private Communication.

[21] Cran, J., "EPE Plant Cost Indicies International", Engineering and Process Economics, p 109-112, 1976.

[22] Happel, J., Aries, R.S. and Borns, W.J., "Estimating chemical engineering equipment costs", Chemical Engineering, p 99-102, Oct 1946.

[23] Nelson, W.L., "Here's a look at productivity in the design and erection of refineries - 1973 and the future", Oil and Gas Journal, p 100-102, May 12, 1975.

[24] Stallworthy, E.A., "Comparative investment cost in Western Europe", Cost Engineering, p 388-397, July 1963.

[25] Grossfinder, F.B., "Capital cost effects on the U.S. chemical industry's foreign competition", Chemical Engineering Progress, vol 58, (3): 60-6, March 1962.

[26] Bauman, H.C., "Costs for chemical process plants abroad", Industrial Engineering Chemistry, vol 54, (9): 40-3, Sept 1962.

[27] Bauman, H.C., "What is the real cost of labour abroad", Industrial and Engineering Chemistry, vol 54, (7): 35-9, July 1962.

[28] Goddard, R. et. al., "Foreign costs and financial factors", A.A.C.E. Bulletin, p 3-8, March 1963.

[29] Johnson, R.J., "Cost of overseas plants", Chemical Engineering, vol 76, p 146, March 10, 1969.

[30] Guthrie, K.M., "Capital and operating costs for 54 processes", Chemical Engineering, vol 77, p 140-156, June 15, 1970.

[31] Reuben, B.G. and Burstall, "The Chemical Economy", Longman, 1973.

[32] Nelson, W.L., "Toatal cost versus capacity and complexity", Oil and Gas Journal, p 55-7, Feb 24, 1975.

[33] Sheridan, M.B., "The challenge of Middle East petrochemicals" Process Economics International, vol II, No 4, 1981.

[34] Boyd, N., "Cost and price indices", Process Economics, vol 7, p 97, 1983.

[35] Eady, C.W. and Boyd, N., Cost Engineering, p 152-7, March 1964.

[36] Arnold, T.H. and Chilton, C.H., "New index shows plant cost trends", Chemical Engineering, p 143-52, Feb 18,1963.

[37] Stevens, R.W., "Equipment cost indexes for Process Industries", Chemical Engineering, p 124-6, Nov 1947.

[38] Cran, J., "Cost indicies help estimate new plant costs", Procees Engineering, p 60-1, April 1983.

[39] National Economic Development Office, Process Plant Working Party Report, No.7, July, 1972.

[40] Cran, J., "Cost indices", Engineering and Process Economics, vol 1, p 13-23, 1976.

[41] Institute of Chemical Engineers, "A New Guide to Capital Cost Estimating", Rugby, 1977.

[42] Bridgwater, A.V. and Bossum, F.D.G., "A new approach to plant cost indices", 6th International Cost Engineering Congress, Mexico City, 1980.

[43] Kharbanda, O.P. and Stallworthy, E.A., "Total Project Management, from Concept to Completion", - (a) p 90
- (b) p 279

[44] "Cracking the productivity measurement problem", Special Report, Plastic Technology, p 76, Sept 1981.

[45] Mark, E.J., "Labour productivity for overseas construction projects", A.A.C.E. Bulletin, p 5-6, Feb 1975.

[46] Mendel, O., "How location affets U.S. plant construction costs", Chemical Engineering, p 120-4, Dec 11, 1972.

[47] Labour Yearbook 1983, United Nations.

[48] Ottaviano, V.B. and Wesler, N., "Productivity: a nightmare for mechanical contractors", A.A.C.E. Bulletin, April 1973.

[49] Gallagher, J.T., "Analysing field construction costs", Chemical Engineering, p 182-91, May 20, 1968.

[50] Edmonson, C.H., "You can predict construction labour productivity", Hydrocarbon Processing, p 167-80, July 1974.

[51] Blough, R.M., "Effect of scheduled overtime on construction projects", A.A.C.E. Bulletin, p 155-61, Oct 1973.

[52] "Doubts over productivity yardstick", Engineering, p 14-15, March 25, 1982.

[53] Rizk, A.W.A., American Association of Civil Engineering Proceedings, p 324-5, July 1980.

[54] Howell, G.A., "Consruction Manager's distance from field work hampers productivity", Civil Engineering, p 71-2, May 1981.

[55] Hussain, A., "Construction productivity factors", American Association of Civil Engineering Proceedings, Oct 1979.

[56] Odams, C.R. and Finlator, T.F., "Construction problems in Western Europe", Chemical Engineering Progress, vol 57, (2): 60-6, Feb 1961.

[57] Nelson, W.L., "Wage ratios and productivity", Oil and Gas Journal, p 134, July 30, 1973.

[58] Nelson, W.L., "Manpower and labour costs", Oil and Gas Journal, Dec 16, 1964.

[59] Nelson, W.L., "Productivity in construction work generally low abroad", Oil and Gas Journal, Feb 24, 1964.

[60] Jacks, R.L. and Eddy, T.A., "How to do business in India", Chemical Engineering Progress, vol 63, (7): 29-63, July 1967.

[61] Clerk, J., "Multiplying factors give installed costs of process equipment", Chemical Engineering, Feb 18, 1963.

[62] Confidential source.

[63] Duffy, G. and Giddy, I.H., "Forecasting exchange rates in a floating world", Euromoney, p 28-35, Nov 1975.

[64] "Entry to Japan won't be easy", Daily Telegraph, June 25, 1985.

[65] Savay, A.C., "Effects of inflation and escalation on plant costs", Chemical Engineering, July 7, 1975.

[66] "The cost of tomorrow's plant", Process Engineering, Oct 1975.

[67] Clarke, F.D., "How to assess inflation of plant costs", Chemical Engineering, July 7, 1975.

[68] Bonano, D.R., "Cost escalation: its impact on purchased equipment", Chemical Engineering, July 7, 1975.

[69] McMahon, L.A., "Analysis of factors which cause inflation" Transactions American Association Cost Engineers, 1978.

[70] Wells, G.L., "Process Engineering with Economic Objective", Lenoard Hill Books, 1973.

[71] Pfeifer, V.F. et. al., "Dialdehyde starch using electrolytic regeneration of periodic acid", Industrial and Engineering Chemistry, vol 52 (3): 201, March 1960.

[72] Lambe, W.H., "Plant cost versus developing country location", Chemtech., p 100-3, Feb 1978.

[73] Lang, H.J., "Cost relationships in preliminary cost estimation", Chemical Engineering, p 117-21, Oct 1947.

[74] McGower, H.C., Chemical Engineering Progress, vol 42, p 327, 1961.

[75] Korevaar, J., "A Dutch Annual Composite Cost Index for chemical and similar plants", 1976 Transactions American Association Cost Engineers, Boston, Massachusetts.

[76] Kay, S.R. et. al., "Cost indices of erected cost of process plants", Cost Engineering, vol 20, (2,3), 1981.

[77] Gerrard, A.M., "PEI two component indices - a comparison with other established indices for W. Germany", Process Economics International, vol IV, No 4, 1984.

[78] Kay, S.R., "Canadian process plant cost indices - a comparison", Process Economics International, vol IV, No 1, 1983.

[79] Stallworthy, E.A., Private communication.

[80] Jenson, V.G. and Geffreys, G.V, "Mathematical methods in Chemical Engineering", Academic Press, 1963.

[81] Matley, J., "CE Plant Cost Index Revised ", Chemical Engineering, p. 153-156, April 1982.

[82] "International Financial Survey", Barclays, Feb. 1985.