CONSTRUCTION DEMAND MODELLING:
A SYSTEMATIC APPROACH TO USING ECONOMIC INDICATORS AND
A COMPARATIVE STUDY OF ALTERNATIVE FORECASTING
APPROACHES

by

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Abstract

The published literature abounds with evidence of a close relationship between the construction industry and the national economy. This study reinforces the strength of this relationship by proposing the use of economic indicators to model demand for construction. Alternative forecasting approaches are applied, comprising both traditional and state-of-the-art techniques. The aim is to establish the most theoretically significant and statistically adequate indicators, and the most accurate forecasting technique for modelling and predicting construction demand.

A systematic approach is proposed to identify and select economic indicators that relate to demand for construction. It involves four distinct stages and they are: (1) theoretical identification; (2) data collection and pre-processing; (3) statistical selection; and (4) usage. This stage-by-stage process is illustrated on residential, industrial and commercial-type construction in Singapore. The findings confirm that demand in the construction industry is significantly related to a wide range of economic measures.

A comparative study of regression and non-regression approaches of forecasting is carried out using Singapore's residential sector as a case-study. The techniques include the Multiple Linear Regression, the Multiple Log-linear Regression, the Autoregressive Non-linear Regression Algorithm and the Artificial Neural Network (ANN). Seven economic indicators have been selected to build the demand models, and they are: Building tender price index; Bank lending for housing; Population size; Housing stock (additions); National savings; Gross fixed capital formation for residential buildings; and Unemployment rate. Quarterly time-series data over the period 1975 - 1994 are used. Several conclusions are drawn. Firstly, non-linear methods produce more accurate forecasts. Secondly, the Multiple Log-linear is the most accurate regression technique. Thirdly, the ANN technique, a non-regression approach, performs outstandingly better than the regression approach.

Keywords: Demand, economic indicators, forecasting, regression, artificial neural network.
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CHAPTER 1

INTRODUCTION

1.1 Background

A country's economic performance has always been closely related to its construction industry. The importance of the construction industry's role in the economy is reflected by its significant contribution to the Gross Domestic Product (GDP) and investment, measured by value added in construction and gross fixed capital formation, respectively. On the other hand, the state of activities in the construction industry is also highly dependent on the well-being of the economy as a whole. Construction is regarded as an investment good, and demand for most buildings is "derived demand", that is, it depends on the demand for goods and services that can be produced from the building or for the utility offered by the building (Hillebrandt, 1974). Generally, firms are more likely to invest in physical assets if they expect demand to remain high and long-term economic conditions to be good. If the general economic outlook is unfavourable, businesses are most likely to cut back on fixed investments owing to their high cost. Hence, activity in the construction industry is very sensitive to the general economic environment, creating uncertainty in the future levels of construction workloads.

According to Hindle (1993a), the short-term business cycle has a direct influence on construction demand which inevitably causes substantial fluctuations. It is also widely believed that construction is more volatile than other sectors in this respect (National Economic Development Office, 1978; Hillebrandt, 1984; and Newcombe et al., 1990). Hence, the construction industry is subject to the detrimental effects of demand fluctuations. For construction firms, adverse effects of cyclical construction demand on their performance and operation were found to exist. Having a distinct impact on firms' production efficiency (Wong, 1985). On a broader basis, Hindle (1993b) examined the general effects of demand fluctuations on the construction industry in different stages of the construction cycle. He cited competition for construction work and resources as the primary effect, while secondary effects included profitability, production volume, quality standards, investment in training, construction delays, investment in research and unity in the industry.

In view of this, knowledge of the level of demand for construction is necessary for a number of
reasons. From a prospective developer's point of view, the levels of demand for various types of buildings would indicate the possibility of a timely and profitable disposal of new developments. The industry should also be aware of the probable levels and nature in order to plan its future workload. At the enterprise level, knowledge of total construction demand enables construction firms to forecast their future workload and to anticipate any significant changes in their share of sectoral demands. It also helps them to operate more efficiently through better planning and control of their activities. At the project level, tenderers who have knowledge of future demand can price their tenders more realistically and strategically, thereby increasing their chances of success, and consequently realising the expected level of profit for the building project.

Despite considerable need to estimate construction demand, it involves a very complex process; and such attempts are fraught with difficulties because of the many differing factors that influence demand for different types of construction. However, upon examination of these factors, Hillebrandt (1984) noted that the general economic situation is a common factor that affects demand for all types of construction. Subsequent studies of construction demand (Oshobajo and Fellows, 1989; Tang et al., 1990; Hutcheson, 1990; Killingsworth, 1990; Akintoye and Skitmore, 1994) have also typically incorporated macroeconomic measures in the modelling process to take account of economic influences.

The need to incorporate a multitude of influencing factors when modelling demand for construction has led to the predominant use of multivariate forecasting methods. In particular, there is an extensive use of the multiple regression approach owing to its relative simplicity in concept and application. Within the domain of this approach, the focus is always on building linear models. Models based on non-linear forms are generally lacking. This is because non-linear regression techniques involve the manual task of specifying functional forms to fit the data, and such judgemental interventions would require the modeller to have an intimate knowledge of past trends of the modelling variables in order to be precise in their specification. In a few studies (Tang et al., 1990; and Akintoye and Skitmore, 1994), non-linearity was considered with the use of the log-linear form. However, the incremental improvement, if any, of going from the traditional linear form to the log-linear form had not been investigated. In any case, there have been recent contentions (Oshobajo and Fellows, 1989; and Goh, 1996) that the incorporation of "expert" judgement or the manual specification of non-linear terms in regression models may introduce an element of biasness and intuition, undermining the objectivity of the forecasts generated by such models.
The inter-disciplinary field of non-linear modelling and forecasting has grown rapidly over the last decade. This is largely due to the increasing availability of computer resources, which both allows for the collection of increasingly large datasets, and the analysis of the datasets with numerically intensive algorithms. Casdagli and Eubank (1991) attributed the growth in the field to the increasing recognition of the ubiquity and importance of the effects of non-linear dynamics in the natural and social sciences. Among a wide range of disciplines working on different aspects of non-linear modelling, advancement in Artificial Intelligence (AI) techniques has been one of the greatest. The use of Artificial Neural Networks (ANNs) to construct non-linear models from time-series data is the most prevalent. In recent years, ANNs have gained popularity as powerful pattern recognition devices that have the ability to perform non-linear modelling and adaptation automatically, without having to make any functional assumptions. They provide a relatively simple way to model and forecast complex non-linear systems.

When several plausible forecasting methods are available, there is a need to choose one which best suits the nature of the variable to be predicted. Demand for construction is generally known to have a volatile trend, amplifying the need for accurate short-term forecasts. Hence, in the evaluation and comparison of different forecasting techniques, accuracy can be used as an effective measure. In general, accuracy is regarded as a vital attribute of all quantitative predictive models and plays an important part in the selection and testing of forecasting techniques (Lawrence, 1983; and Mahmoud, 1984). Thisjustifies the claim by Makridakis et al. (1982) that accuracy is a major factor that has been dealt with in the forecasting literature by empirical or experimental studies. In fact, forecasting techniques ranging from purely intuitive or judgemental approaches to highly structured and complex quantitative methods have been compared solely on their accuracy performance.

1.2 Purpose of research

The published literature abounds with evidence of a need to relate the construction industry with the general economic environment. The effect of economic fluctuations has a major impact on the performance of this sector of the economy. Economic indicators, which are measures of performance of the national economy, may serve as viable input variables to model construction demand. Traditionally, in macroeconomic modelling studies, independent variables are selected systematically by satisfying two main criteria: economic significance and statistical adequacy.
However, this has not been the case in construction demand modelling studies. There has yet to be a systematic approach proposed for variable selection as part of the whole modelling process.

In relation to modelling demand for construction, mainly regression methods have been used in the past, and the focus has been on developing linear models. Therefore, there is a need to examine non-linear regression techniques, using the traditional linear method as a benchmark for comparison. In addition, the application of non-regression methods also needs to be explored, and any improvements tested. Essentially, this would extend the boundary of traditional practices by seeking better alternative techniques for construction demand modelling.

The key to evaluating the performance of different demand modelling techniques is to measure the predictive ability of the derived models. As mentioned earlier, accuracy is the most significant way of assessing forecasting techniques, at least quantitatively. Using relative measures of accuracy, alternative forecasting approaches can be compared.

This study is concerned, inter alia, with the use of economic indicators and alternative forecasting approaches to model and predict demand for construction. More specifically, the purpose of this research is to:

1) Propose a systematic approach to the theoretical identification and statistical selection of economic indicators for construction demand modelling;

2) Critically appraise linear and non-linear regression methods, and a non-regression method of modelling and forecasting demand for construction; and

3) Evaluate and compare the forecasting accuracy of construction demand models that are built using linear and non-linear regression methods, and a non-regression method.

1.3 Terminology

In the process of writing this thesis, a few terminological issues arise. In resolving them, definitions, as well as distinctions are given for these terms. This is to ensure that the terms used in this thesis tailor more specifically to the scope and objectives of the study.

A distinction needs to be made between 'building cycle' and 'construction cycle'. Generally, they
have been used interchangeably to refer to the period between two successive peaks or troughs in the total volume of construction. However a distinction can be made between the terms 'building' and 'construction'. The latter includes, besides the body of knowledge traditionally covered by 'building', considerations of infrastructure and utilities such as roads, harbours and bridges. From this, it can be gathered that building cycles would refer more to construction activities involving buildings only. Writers who have based their works mainly on building cycles are Mitchell (1927), Newman (1935), Hansen (1941), Lewis (1965), Kafandaris (1980) and Bon (1989). This is evident that a clear distinction can be made between the two types of cycles and the common use of the term 'building' rather than 'construction' reflects the fact that cycle theorists have basically concentrated on that particular sector of the industry, especially housebuilding. Kafandaris (1980:298) noted that "almost invariably, cycles were invoked in relation to housing and not to civil engineering works". Building cycles have generally been studied in the context of the whole economy; and a major objective has been to develop appropriate propositions to aid the formulation of policy to stabilise construction activity, mainly through public works. Over the issue of 'building cycles' and 'construction cycles', the former is considered more appropriate as it reflects more accurately the scope of this research.

However, in the context of demand, a distinction between 'building' and 'construction' has not been so clear. The terms 'construction demand' and 'demand for construction' are used, in general, to refer to demand for any type of construction activities, that is, buildings, infrastructure, or both. In view of this, it should be highlighted that where such terms are adopted in this thesis, they refer to demand for construction involving buildings alone, since only such works are examined here.

Economic indicators have been broadly defined as "descriptive and anticipatory data used as tools for business conditions analysis and forecasting" by Zarnowitz (1992:283). He elaborated that "there are potentially as many subsets of indicators in this sense as there are different targets which they can be directed". Similarly, the Economist (1994) also distinguished a wide range of different groups of major economic indicators which cover economic growth, population and employment, government fiscal policies, consumers, investment and savings, industry and commerce, external flows, exchange rates, money and interest rates, and prices and wages. Although economic indicators may be taken in a narrower sense to cover only measures of economic activities, the wider definition is preferred by the writer. Therefore, for the purpose of this study, economic indicators are to be regarded in the broader context, which include social
and demographic measures as well.

It is also necessary to define the term 'traditional', used in the context of the linear regression method. Traditional forecasting methods refer to those which have been practised from the past to the present. In contrast, non-traditional, or state-of-the-art, methods are those that have only recently evolved and are still being explored to determine their viability as practical forecasting tools.

The terms 'approach' and 'method' used in the context of this thesis are different with respect to their scope. A forecasting approach is regarded as having a broader scope and may comprise more than one forecasting method or technique. A method is, therefore, to be considered as a subset of an approach.

Finally, it is apt to mention that discussion of these issues is limited to that required to justify the terms used in this thesis. It is by no means an attempt to redefine them but only to illustrate either the specificity or the diversity of the terms adopted.

1.4 Statements of the problems

Having outlined the limitations and difficulties faced by past construction demand modelling studies, the three problem areas to be addressed in this thesis may be stated as:

The first premise upon which this research is based is that there has been insufficient examination of all possible economic indicators for use in modelling demand for different types of building construction. This may be attributed to the absence of a systematic approach to the identification and selection of economic indicators which satisfy the economic significance and statistical adequacy criteria.

The second premise is that the scope of the forecasting methods used in the past for construction demand modelling has generally been limited to building linear regression models, that is, linearity is assumed at the outset for the relationship between the modelling variables. In cases where non-linearity was considered, only log-linear forms were used. Their improvements, if any, over the traditional linear form have not been investigated.
The third premise is that the scope of non-linear forecasting methods used for construction demand modelling has also generally been restricted to the regression approach. Considering the need of having to manually specify non-linear functional forms to fit the data, there may exist a risk of such methods not modelling the true relationship between the variables, but only the form which the model should take, as subjectively judged by the modeller. The inability of such models to generate good forecasts may be the result of a common failure to explore a non-regression approach such as the ANN technique, which is specially designed to cope with complex non-linear systems.

The final premise is that there has been little or no comparative study of different forecasting methods used to model demand for construction. This has resulted in the adoption of forecasting methods without having an objective view of their strengths and weaknesses, particularly their predictive abilities. This may eventually lead to forecasters of construction demand being without adequate assurance as to the fidelity of their forecasts.

1.5 Objectives of the research

The detailed objectives of this study, therefore, are to:

1) Examine, in theory, the relationship between the construction industry and the national economy;
2) Theoretically identify economic indicators that relate to demand for different types of building construction so that economic significance is achieved;
3) Statistically select economic indicators that relate to demand for different types of building construction so that statistical adequacy is achieved;
4) Propose a systematic approach to the identification and selection of economic indicators for construction demand modelling;
5) Review the theory and applications of linear and non-linear regression methods;
6) Review the theory and applications of the ANN technique;
7) Apply linear and non-linear regression methods, and the ANN technique in a case-study of Singapore's residential sector to model its demand for construction; and
8) Evaluate and compare the predictive ability of the derived demand models in terms of their accuracy.

1.6 Research hypotheses

In addition to fulfilling the objectives set out for this study, three research hypotheses are developed to verify some specific issues arising from this research. They are:

1) Demand in the construction industry is significantly related to a wide range of economic measures such as national output, population and employment, government fiscal policies, national consumption, investment and savings, industry and commerce, balance of payments, money and interest rates, and prices and wages.

2) A non-linear model can forecast demand for construction more accurately than a linear model.

3) The ANN technique, a non-regression approach, can outperform the regression approach in predicting demand for construction.

1.7 Research methodology

Research is the method by which rational inquiry is used to generate new knowledge. It is reserved for activities designed to discover facts and relationships that will make knowledge more effective. According to Skitmore (1988), the basic approach used in academic research is the scientific approach. He cites objectivity and the ability to divide the subject matter in question into smaller parts from analysis as reasons to this standpoint. Earlier, Kerlinger (1973) highlighted that a critical feature of the scientific approach is the notion of problem, hypothesis, reasoning, observation-test-experiment, and conclusions by which the hypothesis is accepted or rejected. Newton (1983) subsequently classified this as the 'top-down' approach and the main phases that describe this approach, as depicted by Bryman (1988), is shown in Table 1.1. On the contrary, the adoption of a 'bottom-up' approach has been advocated by Watkins (1970). This approach emphasizes the collection of data from which patterns or inferences can be drawn,
resulting in the use of inductive reasoning. A clear distinction from the 'top-down' approach is its departure from the need to formulate and prove a hypothesis. Precedents for the 'bottom-up' approach has been set by Atkin (1988) and Bowen (1993).

Table 1.1. The main phases and intervening processes of quantitative research

<table>
<thead>
<tr>
<th>Main Phases</th>
<th>Intervening Processes</th>
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<tbody>
<tr>
<td>Theory</td>
<td>Deduction</td>
</tr>
<tr>
<td>Hypothesis</td>
<td>Operationalization</td>
</tr>
<tr>
<td>Observation/Data collection</td>
<td>Data processing</td>
</tr>
<tr>
<td>Data analysis</td>
<td>Interpretation</td>
</tr>
<tr>
<td>Findings</td>
<td>Induction</td>
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</tbody>
</table>

Relating to research methods, Buckley et al. (1975) classified them into four main types: archival; analytical; opinion; and empirical. Osuala (1982) also established four distinct research methods and they are: historical; descriptive; experimental; and survey. These categories have been similarly adopted by Leedy (1985) and Dane (1990). A different classification was suggested by Kidd and Judd (1986). However, upon close examination, their classification of research methods comprised a combination of the ones identified by Buckley et al. (1975) and Osuala (1982).

For this research, the objectives of the study dictates the adoption of the 'top-down' approach where the conventional 'hypothesis' required by the scientific approach is developed and proven. The research methods employed are the archival and analytical methods as proposed by Buckley et al. (1975). The archival method is required because it concerns the examination of recorded facts. The main advantage of this method is its ability to access and manipulate a vast quantity of hard, and often factual, information. It is most suitable for the analysis of historical data in an attempt to identify data patterns and extrapolate these patterns into the future to make forecasts. The analytical method is also useful as it involves breaking down the problem into its component parts so that its true nature and the causal relationships of the variables of interest may be determined.
Consequently, the research methodology employed in this study can be detailed as follows:

1) A comprehensive literature review of the topics involved in this research;
2) An archival approach to the collection of vast quantities of data relating to national level statistics;
3) An analytical approach to the theoretical and statistical selection of economic indicators that are significantly related to demand for different types of building construction; and
4) A combination of archival and analytical approaches for the application, comparison and evaluation of the various forecasting methods used to model and predict demand for construction.

1.8 Scope of the research

The scope of this research can be divided into three main parts.

The first part of the study aims to develop a systematic approach for the identification and selection of economic indicators for construction demand modelling. First, it involves a comprehensive literature review of the relationship between the construction industry and the national economy. Second, theoretical issues of construction demand and economic indicators are discussed, serving as introductory chapters to the empirical study. Third, the process of theoretical identification is carried out based on a literature review of all possible economic indicators that are associated with demand for different types of building construction namely, residential, commercial and industrial. Civil engineering works involving the construction of infrastructure and utilities are excluded. Finally, for the statistical selection process, Singapore data is utilised and the statistical technique known as the Step-wise procedure is applied.

The second part involves the application of linear and non-linear regression methods, and the ANN technique, a non-regression approach, to model and predict demand for residential construction in Singapore. Economic indicators selected in the first part of the study are used as modelling variables. The regression methods are namely, the Multiple Linear Regression, the Multiple Log-linear Regression and the Autoregressive Non-linear Regression Algorithm. The ANN technique is used to represent the non-regression approach. The individual derived model
is subsequently used to generate forecasts of residential construction demand in Singapore.

The third and final part consists of a comparative study of these forecasting techniques. With accuracy chosen as the quantitative criterion of evaluating and comparing the different techniques, relative measures based on percentage errors are employed to establish the most accurate predictive model of residential construction demand in Singapore.

Although only Singapore data is utilised in the quantitative study, it should not be considered as a limitation. The scope of this research requires an in-depth study into a wide range of economic indicators and forecasting techniques. The case study of Singapore alone entails the collection and analysis of a massive amount of data. Therefore, owing to time constraints, it is only possible to carry out quantitative analyses of one country's data. However, the general approach of this study can be treated as a methodological framework which may be applied in the context of other countries.

1.9 Structure of the thesis

This thesis comprises a total of 11 chapters and the content of each chapter is briefly outlined below.

Chapter 2 sets out to establish an economic relationship between the construction industry and the national economy. General issues such as the following are discussed:

a) the nature of building cycles and their relationship with business or economic cycles;
b) the construction industry in the context of the national economy;
c) the impact of a change in government policies (i.e. fiscal, monetary, balance of payments) on the level of demand for construction;
d) the role of government in the construction industry; and
e) the role of the construction industry in socio-economic development and long-term economic growth.

Specifically, the role of Singapore's construction industry in the national economy is examined here.
Chapter 3 is a general discussion of the need to forecast demand for construction, the nature of demand cycles, and the measures, or forward indicators, of demand.

The level of performance of a national economy can be monitored via economic indicators. Some of these include the GDP, the Consumer Price Index, prime-lending rate, industrial production, unemployment rate, housing starts, etc. Basic information on the scope, significance and interpretation of some key indicators are provided in Chapter 4.

The objective of Chapters 5 and 6 is to identify and select economic indicators that relate to demand for different types of building construction. There are two selection criteria adopted namely, economic significance and statistical adequacy. Chapter 5 deals with the process of theoretical identification, while Chapter 6 undertakes the statistical selection of indicators based on a case-study of Singapore.

Following the steps adopted in Chapters 5 and 6, a systematic approach is proposed and described in Chapter 7 for the identification and selection of economic indicators for modelling construction demand. A schematic representation of the approach is also given.

The next two chapters review the regression and non-regression approaches to modelling and forecasting construction demand. Chapter 8 comprises a comprehensive literature review of past works on construction demand modelling and forecasting. The emphasis is on describing the traditional regression methods that have been adopted. The ANN technique, a non-regression approach, is introduced in Chapter 9. Aspects of theory and application are discussed.

The scope of Chapter 10 is a case study of the residential construction sector in Singapore. It involves the application of linear and non-linear regression methods, and the ANN technique to model and predict demand for residential construction in Singapore. The economic indicators selected in the earlier stages serve as input variables for these models. The predictive ability of these models is assessed and compared by adopting some relative measures of forecasting accuracy. The strengths and weaknesses of each approach are generally discussed.

Chapter 11 reviews and summarises the findings of the research. Recommendations for future work in this area are also made.
Figure 1.1 shows the layout of the 11 chapters described above. It provides an overview of the linkages between the chapters which together form the structure of this thesis.
Introduction

Chapter 2
Relationship between the Construction Industry and National Economy

Chapter 3
Theory of Construction Demand

Chapter 4
Theory of Economic Indicators

Chapter 5
Theoretical Identification of Economic Indicators for Modelling Demand for Different Types of Construction

Chapter 6
Statistical Selection of Economic Indicators for Modelling Demand for Different Types of Construction: THE CASE OF SINGAPORE

Chapter 7
A Proposed Systematic Approach to Identifying and Selecting Economic Indicators for Construction Demand Modelling

Chapter 8
The Regression Approach to Forecasting: Theory and Applications

Chapter 9
Artificial Neural Networks: Theory and Applications

Chapter 10
Construction Demand Modelling using Alternative Forecasting Approaches: THE CASE OF RESIDENTIAL CONSTRUCTION IN SINGAPORE

Chapter 11
Conclusions and Recommendations

Figure 1.1 Chapter Layout and Structure of Thesis
A REVIEW OF THE RELATIONSHIP BETWEEN THE CONSTRUCTION INDUSTRY AND THE NATIONAL ECONOMY

2.1 Introduction

Chapter 2 is a theoretical review of the link between the construction industry and the national economy. In essence, the construction industry is studied in relation to its role in the national economic system, macroeconomic policies, and economic development and growth.

The chapter begins by looking at different definitions of the construction industry. Some definitions are also provided for the national economy to explain key concepts relating to output, growth, inflation, employment, and import and export. All these are covered in Section 2.2.

Section 2.3 examines the relationship between building and business or economic cycles. First, the nature of building cycles is discussed in relation to changing levels of demand for construction. As demand for construction is influenced by the level of economic activity, the interaction between building and business cycles is drawn upon next.

The importance of the construction industry in the national economy is discussed within the scope of macroeconomic theory in Section 2.4. The contributions of the construction industry to national aggregates such as output, consumption and production are highlighted. The relations between construction and other sectors of the economy are also examined.

Owing to the significant role played by the construction industry in the national economy, any change in one will have a strong impact on the other. Most often, changes are activated through government's adoption of different sets of economic policies. The relations between construction and various economic policies are explored in Section 2.5.

The role of the construction industry in socio-economic development and long-term growth of an economy is considered in Section 2.6. Specifically, the role of construction in both developing and developed countries is discussed. Factors and conditions of long-term growth in an economy are discussed, highlighting their influence over future construction activities.
The chapter concludes with Section 2.7 which, in essence, aims to bring together the various issues discussed in the preceding sections. It involves a review of the relationship between the construction industry and the national economy of Singapore, focusing particularly on the vital role of construction in Singapore's socio-economic development over the past few decades.

2.2 Definitions

Many definitions have been given for the construction industry, varying in terminology and scope. Some writers attempt to define it based on the nature of the construction process and features of the industry's products, which merely indicates what the construction industry includes or does not include. Construction has been described by Colean and Newcomb (1952), and Lange and Mills (1979) as an aggregation of businesses engaged in closely related activities. Nam and Tatum (1989) refers construction to all types of activities associated with the erection of and repair of immobile structures and facilities. Other writers extend their definitions to include the services provided by participants in the construction process. Cassimatis (1969:10) defines separately "construction" and "contract construction" to distinguish the difference between the activities involved in construction and the provision of construction services. Together, they constitute the "contract construction industry". His definitions are as follows:

"construction refers to all types of construction activity usually associated with the erection and repairs of immobile structures and facilities, such as, buildings of all types, highways and streets, ports and airports, dams and conservation projects, railroad lines and canals, and other similar types of work"; and

"contract construction refers to an industry consisting of a large number of firms that perform construction work for others."

Hillebrandt (1984) defines construction as covering the parties involved in the construction process and, to some extent, the suppliers of the industry's inputs. She also distinguishes the contracting part of the industry as one which:

"undertakes to organise, move and assemble the various materials and component parts so that they form a composite whole of a building or other works, and the product which the
contracting industry is providing is basically the service of moving earth and material, of assembling and managing the whole process" (Hillebrandt, 1985:24).

In view of all existing definitions, Ofori (1990:23) proposed a broad outline of construction which defines the industry as:

"that sector of the economy which plans, designs, constructs, alters, maintains, repairs and eventually demolishes buildings of all kinds, civil engineering works, mechanical and electrical engineering structures and other similar works. Thus, the industry includes: persons, enterprises and agencies, both public and private, involved in physical construction..., and those providing all kinds of planning, design, supervisory and managerial services relating to construction."

It is only in this latter definition that the construction industry has been viewed and described as a sector of the general economy. A broader definition needs to be established in order to reflect the importance of the construction industry in relation to the national economy. It may serve as a supplement to the earlier definitions which mostly describe the construction industry too narrowly and in isolation. For the purpose of the study, a macroeconomic definition is proposed which describes the construction industry as:

"that sector of the economy which contributes significantly to the country's socio-economic development, employment, fixed capital formation, capital investments, and balance of payments in terms of import and export of construction services and inputs. Its interdependence with other sectors of the economy is reflected by its need for inputs from the other sectors and its largely derived demand. Owing to this, the satisfactory performance of the construction industry is vital for the well-being of several other parts of the economy, and vice versa. It may also serve as a regulator of the economy, due to its size and importance, and its prospects have a major effect on the general economic condition of the whole economy."

With regard to the national economy, there are a few key concepts that are central to evaluating macroeconomic performance. They are mainly related to output, growth, inflation, unemployment and foreign trade. These concepts are defined and elaborated as follows:
1) Gross national output

Gross National Product (GNP) is defined as the value of all final goods and services produced by domestically-owned factors of production within a given time period. It is the basic measure of economic activity. In relation to GNP, three important distinctions have to be made and they are:

a) GNP and GDP

GDP is defined as the value of final goods and services produced within the country within a given time period. This implies that part of GNP is earned abroad. For example, when GNP exceeds GDP, residents of a given country are earning more abroad than foreigners are earning in that country. GDP is often viewed as a better measure than GNP and is generally accepted by all major industrialised countries (The Economist, 1994). The difference between GNP and GDP is usually relatively small, perhaps 1 per cent of GDP, but there are a few exceptions, for example, in 1989 Kuwait's GNP was 35 per cent larger than its GDP, due to the country's vast income from foreign assets.

b) Nominal and Real GNP

Nominal GNP measures the value of output at the prices prevailing in the period during which the output is produced, while real GNP measures the output produced in any one period at the prices of some base year. Real GNP, which values the output produced in different years at the same prices, implies an estimate of the real or physical change in production or output between any specified years. When there is a difference between the growth rates of nominal and real GNP, it is often attributed to the rising of prices of goods or inflation. The rate of inflation is defined as the percentage rate of increase of the level of prices during a given period of time. The most common way to measure the overall price level is the consumer price index (CPI). The CPI measures the cost of a fixed basket of goods bought by the typical urban consumer. Generally, the growth rate of the economy is determined by the rate at which real GNP is increasing.

c) GNP and GNP per capita

Another measure of real GNP is established by looking at national output per person. GNP per capita is derived by adjusting the value of total output by the size of the population. This
measure is used as an indicator of overall economic welfare. The growth rate of real GNP per capita is the most important of all the macroeconomic indicators by which to judge the economy's long-run performance.

2) Employment and unemployment

One major objective of macroeconomic policy is high employment, which also requires low unemployment. The unemployment rate is defined as the fraction of the labour force that is out of work but is ready and able to work. It serves as an indicator of spare labour capacity or wasted resources in an economy.

High unemployment rates are a major social problem. The unemployed suffer a loss in their income, standard of living and career opportunities. Besides being one of the most important social and political issues, high levels of unemployment also impose great costs on society.

3) Foreign economic policy

This policy deals mainly with the import and export of goods and services, and the borrowing and lending of money to foreigners. Net exports is defined as the difference between the dollar value of exports and the dollar value of imports. It can also be regarded as the trade balance, which is defined as the net balance between exports and imports of goods.

Since trading is involved between countries, the price of one country's currency in terms of another has to be monitored. The foreign exchange rate of a given country represents the price of its own currency in terms of the currencies of other countries. When a country's exchange rate rises, its export becomes more expensive and, therefore, is less competitive in world markets, causing exports to shrink relative to imports. By contrast, when a country's exchange rate falls, import prices rise and the inflation rate also tends to increase. These impacts on the economy make the exchange rate increasingly important for all countries.

In general, when net exports turn to deficit or surplus, or when the foreign exchange rate rises or falls sharply, countries move to correct the imbalance in their foreign economic relations.

In summary, the objectives and instruments of macroeconomic policy are listed in Table 2.1.
Table 2.1: Objectives and instruments of macroeconomics

<table>
<thead>
<tr>
<th>OBJECTIVES</th>
<th>INSTRUMENTS</th>
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<tbody>
<tr>
<td>Output:</td>
<td>Fiscal policy:</td>
</tr>
<tr>
<td>-High level</td>
<td>-Government expenditure</td>
</tr>
<tr>
<td>-Rapid growth</td>
<td>-Taxation</td>
</tr>
<tr>
<td>Employment:</td>
<td>Monetary policy:</td>
</tr>
<tr>
<td>-High level of employment</td>
<td>-Control of money supply affecting interest rates</td>
</tr>
<tr>
<td>-Low involuntary unemployment</td>
<td></td>
</tr>
<tr>
<td>Price-level stability with free markets</td>
<td>Foreign economics:</td>
</tr>
<tr>
<td></td>
<td>-Trade policies</td>
</tr>
<tr>
<td></td>
<td>-Exchange-rate intervention</td>
</tr>
<tr>
<td>Foreign balance:</td>
<td>Income policies:</td>
</tr>
<tr>
<td>-Export and import equilibrium</td>
<td>-From voluntary wage-price guidelines to</td>
</tr>
<tr>
<td>-Exchange-rate stability</td>
<td>mandatory controls</td>
</tr>
</tbody>
</table>


2.3 The relationship between building cycles and business or economic cycles

2.3.1 Nature of building cycles

The pattern of construction activities is typified by cyclical fluctuations, which are mainly caused by changing levels of demand. Since demand for construction is essentially 'derived demand', an increase or decrease in economic activity, would result in a change in demand for goods and services, thus affecting the level of construction activity. Hence, it is possible to outline the nature of a building cycle of a typical construction industry when reference is made to the general economic environment.

In a period of economic expansion, increased economic activity causes an upsurge in demand for goods and services as incomes rise. Throughout the early stages of expansion, all the economic agents involved experience increasing pressure to expand their own facilities. Firms either expand their existing facilities or build new premises to raise production. Individuals may
purchase dwellings, while real estate developers may start considering new investment projects. With a general trend of rising standard of living, government may have to spend more on public building works such as housing, hospitals and schools. These will lead to an overall increase in the demand for construction. If the industry is operating below capacity, the unused resources will be utilised. Construction firms will take measures to increase productivity and secure more work. With increasing demand on building resources, prices of materials and wages will generally rise. Meanwhile, new construction firms will emerge as a result of better perceived profits. However, at some point in time, difficulties will be experienced by those involved in the evermore intensive construction activity. Productivity and efficiency in the industry will start to fall, while wages are still steadily increasing. If demand continues to rise, the industry will reach its capacity. Resources will have been spread fairly thin by the expansion and becoming scarce, projects will be delayed and costs become abnormally high.

Government may intervene to control the inflationary spiral by increasing interest rates. High interest rates will usually mark the end of the economic expansion. With credit restriction, general investments become less attractive. Demand for construction items will fall as they are regarded as expensive capital goods. By then, construction may be priced out of reach of most people. In the construction industry, the combination of rising interest rates and spreading cost increases will create cash-flow problems for some construction firms. Nevertheless, construction projects will still proceed at the expense of anticipated profits. With prospects of the economy looking less bright, demand for construction continues to fall. With fewer projects available for tender in the industry, competition is keener and tender prices become lower. Construction firms will have to reduce their costs by shedding excess capacity and increasing productivity. Investments in the training of personnel and in plant and machinery will be reduced. Less efficient firms will be forced out of business while others continue to survive. In a period of excess capacity in the construction industry, the prices of materials, labour, and plant and machinery will start to fall. When prices have fallen to a level which makes investments in construction become viable again, it may signal the upturn of another building cycle.

2.3.2 Interaction of building and business cycles

Past studies of building cycles have repeatedly drawn upon the interaction between business and building cycles. Although early studies have focused mainly on either building cycles or business cycles, it was inevitable that the phenomena of either type of cycles cannot be explained without
making reference to the other. Mitchell (1927), the pioneer of business cycle studies, observed that in a period of relative prosperity, the construction industry adds sharply to the level of aggregate demand, leading to increases in prices in the economy. Hansen (1941), another business cycle theorist, attributed the level of capital formation to economic and social factors such as population growth, the opening of new territories, discovery of new resources, widening of capital, deepening of capital and technological innovation. In one of the earliest studies of building cycles, Lewis (1965) concludes that changes in population, availability of credit and external shocks such as wars generate building cycles.

In more recent studies, Kafandaris (1980) investigated the relationship of building and business cycles and attempts were made to identify the causes, describe the nature and determine the duration of various cycles. The residential building cycle was studied by Hall and Richardson (1980) and the major factor found to affect builders' perception of demand was the number of loans made to first-time buyers. This in turn is related to monetary issues such as average bank deposit, average repayment of first-time buyers and average earnings. Bon (1989) also relates building cycles to business cycles and discusses how economic fluctuations affect fluctuations in building activity. His detailed account of the stages of a building cycle illustrates the strong influence of business conditions over demand for construction. A quantitative study carried out by Tan (1989) confirms that a close link exists between building and business cycles in Singapore. He suggests that commercial developments generally lead upswings in construction activity, followed after a few months by residential buildings. Ofori (1990) also noted the strong impact that economic conditions have on construction demand in his outline of the features of a typical construction industry at each of the two extreme points in a building cycle. Another quantitative study was undertaken by Hill (1991) which examines the relationship between building and business cycles of six major economies over a 16-year period (1970 to 1986). Correlation analyses were carried out between individual country's growth figures for construction and GDP. The countries found to have a strong correlation between the growth of the economy and construction were Germany, Italy, Britain and the United States. Only Japan and France were found to have a moderate correlation. Correlation values as high as 0.8091 were obtained which implies that a strong and direct relationship exists between building and business cycles in general. Most recently, Hindle (1993a) examined the effects of the short-term business cycle on the construction industry and observed that the demand for buildings and the business cycle behave in relation to each other; demand is seen to increase in the growth phase and to recede in the recession phase.
2.4 The construction industry in the national economic system

2.4.1 Construction and macroeconomic theory of the economy

In this sub-section, the context of the construction industry in the national economy is examined within the scope of macroeconomic theory. As the theory concerns the study of the behaviour of the economy as a whole, it is useful to relate construction to some vital macroeconomic measures so as to establish the role played by the construction industry in the national economy.

2.4.1.1 Construction and national output

National output is the most important measure of overall economic activity; and in any economy, construction is a key activity. The strong influence of construction over output, or vice versa, has often been highlighted by writers. Hillebrandt (1974) attributes the economic importance of the construction industry to its size, which can be measured and expressed in terms of its significant contribution to GDP, GFCF or total employment. In essence, it means that construction has a direct influence on an economy's total output. Briscoe (1988:3) also emphasised that construction "influences the final flow of goods and services produced in the economy - gross national product - and in turn is influenced by the size of that gross national product". He explained that construction output is a response to the demand for buildings, which is derived demand for other products and services; and variations in the GNP will influence the demand for construction work and the associated level of employment. On the other hand, the construction sector also determines the demand for products from other parts of the economy, especially the material supplies sector. Therefore, changes in the level of construction activity will lead to further changes in supplying industries and services, which ultimately feeds back into the overall level of national output.

In an earlier study, Turin (1969) found that the size of contribution of construction to national output does reflect the level of economic development of a country. The findings indicate that construction accounts for 3 to 5 per cent of the GDP in most developing countries and 5 to 9 per cent in most industrialised countries; capital formation in construction accounts for 7 to 13 per cent of the GDP in most developing countries as compared with 10 to 16 per cent in more than half of the industrialised countries; and the industry employs between 2 and 6 per cent of the
labour force in developing countries and between 6 and 10 per cent in industrialised countries. On the other hand, it was also found that for most industrialised countries, between 20 and 25 per cent of the GDP is devoted to gross capital formation, while for developing countries only between 12 and 16 per cent; and in most countries construction represents between 45 to 60 per cent of all fixed capital formation.

2.4.1.2 Construction in relation to national consumption and production

The construction industry serves directly and indirectly the needs of households, which may be considered as the most important element in the economic and political system in most countries (Andersen and Pedersen, 1976). Figure 2.1 illustrates the relationship between construction and total consumption and production in an economy. The households indirectly determine the composition of production by their needs for consumption and public services. All trades, public or private, including construction, serve households in two main ways: they supply households with goods and services demanded; and they provide employment opportunities for the households so as to create income. Therefore, households in most countries influence the allocation of goods and services, among them construction activities, through income, as voters in the political system, as consumers and as participators in the production process.

Construction serves households directly by providing housing and leisure facilities, and indirectly as a means of production and services through all the other supplying sectors. The degree of indirect utility of construction depends on the production functions of the goods and services required. In the case of educational services, school buildings may be considered almost as a direct supply of utility for households, whereas in the case of a factory, the building has a much more indirect utility, because it only houses the activities needed to produce consumer goods. In the case of transport facilities, construction is utilised both directly by households as well as more indirectly through providing transport for the trades.

2.4.2 The context of the construction industry in the national economy

Raftery (1991) introduced a conceptual framework which locates the construction industry in respect to the economy and the property market. Figure 2.2 is a schematic representation of this relationship. In this context, it can be seen that general economic conditions have a direct influence over both the supply and demand for construction. This again highlights the close
Figure 2.1 Relations between Consumption, Production and Construction
relationship between the economy and the construction industry, and the strong influence that the former has over the latter with regard to its well-being.

On the demand side, construction is required by three distinct types of clients: firms in both the public and private sector who need building space as part of their production processes; investors who demand building space as part of their investment portfolio; and individuals and families who demand housing for private consumption. As the demand for most buildings is derived demand, its level depends largely on the demand for goods and services that can be produced from the building or for the utility offered by the building. On the supply side, both the building stock and the construction industry is supplying the construction market with existing and new or refurbished buildings. Demand for built space may be satisfied from the existing stock of buildings or by the purchase of a new or refurbished building from the construction industry. Thus, the construction industry exists at the interface between, on the one hand, the supply of existing buildings, and the other, the general conditions of demand prevailing in the economy. The construction or property market is the meeting point between buyers and sellers of space or property.

As highlighted earlier, the general economic conditions can have a strong impact on the construction industry. Hillebrandt (1984) regarded the general economic situation and expectations as the first and most obvious aspect of the environment that affects all construction demand. In a buoyant economy with expanding economic activities, demand for goods and services increases as the general income level rises. Firms will need to expand their businesses, individuals may be more keen to purchase dwellings, and property investors will be more eager to increase their investments. Government's spending on social and physical infrastructure will also need to increase so as to keep in pace with the rising standard of living in the country. All these will lead to an overall increase in the demand for construction which will have a positive impact on the construction industry. On the contrary, when economic conditions are not favourable, the whole scenario will be reversed and very low demand for construction will be created. Postponement of investment plans on construction will be one of the first signs of an economic downturn because construction is generally regarded as very expensive.

2.4.3 Construction and other sectors of the economy

The output of the construction sector has been described by Briscoe (1988:7) as "a response to
Figure 2.2 The context of the Construction Industry in the National Economy
demand for new investment, for replacement of existing buildings and also for intermediate input into other industries. The nature of derived demand for construction output has often led to the perception that only the construction sector is dependent on other sectors for its output. There is, in fact, a strong interdependence between them. On the one hand, most industries purchase some construction output in order to produce their final products and services, but on the other, the construction sector also purchases a very significant proportion of its material and service inputs from these other sectors of the economy. The construction sector, with its large input requirements, is a major influence on other economic sectors as well. Generally, key inputs are required from the engineering industries, the materials distribution sector, the transport industries and particularly from the financial and professional services sector. Evidently, the construction sector has become a key customer for many industries in the economy. When final demand for construction output declines, the impact will be felt in many other dependent sectors. Therefore, in essence, the interrelationship of construction with other economic activities is such that it is both a determinate for, and a determinant of, general economic development (Economic Commission for Europe Secretariat, 1976). An intersectoral study by Massood (1987) closely examined the interrelationship between construction and the other major production sectors of the economy in 100 countries. It was found that a significant dependence exists between manufacturing and construction particularly at higher levels of manufacturing output. It was also noted that substantial revenues from the exploitation of mineral resources had enabled some developing countries to finance large-scale construction work programmes, thus accelerating development and economic growth in those countries.

2.5 The role of the construction industry in economic policy

2.5.1 Government as a public client

The government plays a complex and varied role in relation to the construction industry. It acts as the legislative authority imposing external constraints on construction and also as participant at different levels in the building process. It is the latter that has far-reaching effects on the industry and the economy because government, as a public-sector client, has the means to exercise very direct control over the demand on the industry and the way it is put to the industry. Occasionally, investment in construction, by itself, is used by the government to introduce desired changes in the economy. Government has often regarded the construction industry as a
tempting regulator of the economy because of its size and importance. Counter-cyclical spending in construction has been used to reflate the economy by the government. Lange and Mills (1979) refer to the industry as the "balance wheel of the economy". Dauten (1961) observed that during an economic expansion, the rise in government construction expenditures seems to coincide with increased activity in the private sector, while during recession, government activity nearly always exceeds the construction generated by all others. Nevertheless, one difficulty often encountered by the government in using construction as an economic regulator is the problem of timing the action so that the effects of the action occur at the correct time to achieve the desired objective (Hillebrandt 1985). Stone (1983) highlighted the dangers of using construction to regulate the economy. The negative effect may be to attempt more than the construction industry can handle and hence of reducing efficiency and raising costs without increasing output of the industry. As a result, national resources may be used less efficiently than before. He, therefore, emphasized that government action is only likely to be successful if it is based on a very thorough understanding of the industry and the way it operates in the economy.

The public sector is the most important single investor in construction in most countries, often accounting for more than half of the total annual investment in construction. The types of construction work that the public sector is most directly concerned are those related to transport and communications, defence, public buildings for education, health and social welfare, housing, and public utilities. The relative importance of each varies from country to country according to the political, social and economic system, local traditions and the particular programme concerned. However, the role of the public sector as a client of the industry in developing countries is probably generally greater than in developed countries. In developing countries, there is an overriding need for improved infrastructure and this is reflected in the greater share of infrastructure in the total construction output in poorer compared with richer countries (Turin. 1973). This view is also shared by Stone (1983) who pointed out that governments tend to have a dominant role in construction in developing countries, as main client for construction work, since the development of the economy depends, to a large extent, on the provision of buildings and works.

But, in contrast to being a major generator of construction activities in an economy, the public-sector client is also capable of impeding construction during periods of economic austerity. Since public construction projects are mostly massive and expensive, they become attractive targets for omission or postponement when public-sector development budget is subject to cutbacks. As
public construction work constitute a significant portion of total demand for construction, overall demand for the industry's activities is particularly vulnerable to fluctuations. Therefore, the competent role of the government in regulating construction activities in the industry is also vital as such fluctuations will, in turn, have a direct impact on the general state of the economy.

2.5.2 Economic policy and the construction industry

It is often experienced that the construction industry is very sensitive to changes in economic conditions, due to its investment character, its use of many industrially produced goods and building materials, and its effect on employment. Most countries have also experienced the controversy between managing demands of the construction industry to achieve stable economic conditions and the need to control the national economy effectively so as to regulate construction activities.

Economic policy is part of the total policy of a government aimed at achieving four central macroeconomic goals: economic growth; full employment; price stability; and equilibrium in the balance of payments. Generally, the main approach is through the management of aggregate demand. In short, a government can increase aggregate demand by either increasing planned injections into the economy or reducing the planned level of leakages. If increases occur in consumer expenditure, government expenditure net of taxation, investment spending and exports net of imports, the national income level is boosted and aggregate demand would deemed to have increased. A government, therefore, through its policy instruments, namely, fiscal, monetary, wage-price, and balance of payments policies, is able to change the planned components of aggregate demand. Ruddock (1992) pointed out that these instruments also give the government an important degree of control over the private sector of the economy, and their effects on the level of investment are important for the construction industry. Investment expenditure is a strategic component of aggregate demand and construction activity accounts for a major part of investment.

The strong influence of government policy over construction output was suggested by Cannon (1978) when she regarded the former as one of the main factors to be taken into account when forecasting the latter. Therefore, it is often advocated that governments should use the construction industry as a means through which to influence the national economy (Stone, 1983). All these imply that economic policies directed at varying the level of construction demand can
be used by governments with an intention to affect the overall level of activity in the economy. In essence, construction demand should be increased, by guiding programmes of direct spending towards this industry, when the economy needs a boost to revive economic activity through the multiplier effect. However, it should be reduced, by intentionally restricting the volume of construction output, when additional activity is merely resulting in inflation during times of economic hyper-activity.

The government, in general, is in a strong position to effect orders for construction through the use of policy instruments. Besides being able to affect the industry directly as a public client, the government can also control private orders directly through physical controls, licences or permits, or indirectly through credit control and market operations which affect the rate of interest or availability of finance, and taxation. Government's control of the private sector is, however, negative; it can effectively reduce orders but can only stimulate and not create orders.

2.5.3 Changes in economic policy and their impact on the construction industry

This sub-section attempts to discuss two main issues: first, the use of some key policy instruments to influence the level of construction demand; and second, the impact of a change in them on total demand for construction. The significant role played by the construction industry in the national economy implies that any change in demand for construction will in turn affect aggregate demand in the economy. It is on this basis that the government will use the construction industry as a regulator of the economy, that is, to increase or decrease demand on the industry with the intention of affecting the overall level of activity in the economy.

2.5.3.1 Fiscal policy

The most direct way of managing the components of aggregate demand is through fiscal policy. It is a policy instrument used by the government to set the levels of taxation and expenditure to affect macroeconomic performance. Hence, it has two main aspects, public taxation and public expenditure, and both of them have a significant impact on the construction industry. Changes in fiscal policy, designed to realise one or more of the main economic objectives, usually have marked implications for the level of demand for construction.

In particular, the amount and the direction of public expenditure is especially important. A large
share of the construction output usually results from direct government commissions or from works which are carried out through major government funding. Essentially, government's expenditure in gross fixed capital formation comes under two main categories. First, the government undertakes direct investment in the provision of public housing, infrastructure and social amenities. Second, the government makes capital grants to the private sector to enable investment to take place. A large proportion of such capital spending is directed towards buildings and works, although expenditure on plant and machinery is also incorporated within this. Changes in both the level and composition of these capital expenditures are therefore highly significant for the construction industry.

Although less direct, public taxation also has an effect on the construction industry. The main source of government revenue is taxation, and income tax is the largest and thus most important component of it. Income tax is also a critical determinant of personal disposable income and it is this received income which determines the spending ability of individual households. A reduction in the rate of income tax effectively increases the spending power of households who may then be more able or willing to spend their money on housing and associated construction work. However, on the other hand, it also reduces government revenue which in turn has a direct impact on future public expenditure. Another form of taxation that has an indirect impact on the construction industry is corporation tax, one that is levied on the profits of firms. A change in the rate of corporation tax by the government simply means that firms would either have more or less incentive to invest in new buildings. The form of taxation that has the most direct significance for the construction industry is the value-added tax. It is a consumption tax levied as a percentage of the value of a wide range of goods and services. It has the effect of increasing the cost of construction and thus affecting overall demand for construction.

When the government is seeking to increase aggregate demand by the use of fiscal policy, it can either increase expenditure or reduce taxation, or a combination of both. However, the multiplier effect associated with an increase in expenditure tends to be greater than that derived from a decrease in income tax. In order to activate the multiplier effect through capital expenditure in construction, the government has to initiate and invest in some public construction works. The initial payments would be made to the participants of the construction project. This first group of individuals would then spend a high proportion of the income they receive on goods and services provided by a second group of individuals and, in this way, would enhance the income of the second group. In turn this second group would spend their income on other goods and
services. Therefore, the value of the initial investment by the government is multiplied by successive rounds of spending and the growth of national income is only checked by leakages out of the economic system such as savings, imports and taxation. The result for the economy is an overall increase in aggregate demand and an expansion of the GNP. The economic impact of increased public spending on construction has been closely examined by Ormerod (1984). His study showed that a nation can invest in its infrastructure, such as roads and housing, and can achieve the physical results of this investment while at the same time creating new, real jobs, increasing company profits through the whole economy, and having other beneficial effects at a minimal cost to the inflation rate. The initial investment would act as a catalyst to the creation of new businesses and self-employment, in addition to increased employment. It would also increase opportunities for established industry and commerce. Hence, the increased spending would have an overall beneficial effect on the economy and the impact is unequivocally favourable to employment, construction output and real profits, providing real opportunities for increased economic activity in the private sector which forms the focus of possibilities of substantial renewed investment by private industries. In another study (Ball and Wood, 1994a), significant relations were found between employment and construction output, indicating again that extra public expenditure on construction is the policy to alleviate demand deficient unemployment.

2.5.3.2 Monetary policy

Monetary policy is an instrument used by the government, in conjunction with the central bank, to regulate the volume of money circulating in the economy. Through such a policy, the government manipulates aggregate demand by using interest rates and credit availability, together with its control of the money supply. The impact of monetary policy on the construction industry is considerable, as interest rates are important determinants of the willingness and ability to undertake investment in buildings and other construction works. When monetary policy tightens the availability of loans and raises the cost of borrowing, demand for construction is likely to be significantly reduced as actual construction and the purchase of property both depend heavily on borrowed funds.

The construction industry is especially sensitive to changes in the general level of interest rates. All types of construction work is financed by loan capital and an increase in the price of borrowing is likely to lead to delays in commissioning new work or to a reduction in sales of
speculative buildings and dwellings. High bank interest rates usually result in higher mortgage rates, and this rapidly chokes off some of the demand for private dwellings. Higher rates also affect property developers who are especially sensitive to changes in interest rates. Commercial clients may have to postpone investment plans for new business premises owing to the increased cost of investment. Construction firms are particularly affected by rises in interest rates. Apart from the impact on demand, higher rates cause profitability and liquidity problems for many construction firms. Some may attempt to pass on the higher costs to consumers through higher prices, but this may serve to reduce demand even further. Those who cut prices in order to secure declining orders may have to be content with lower profit margins. As cost of borrowing rises, other pressures include slower payment by clients and shorter period of credit given by building materials suppliers.

Monetary policy and fiscal policy are usually considered complementary to one another. In this context, fiscal policy is commonly seen as a more effective instrument to stimulate a depressed economy, and monetary policy as a means to dampen an inflated economy (Harms and Buykx, 1976). However, investment decisions are not only taken on the basis of the level of interest rates; the possibilities of internal financing and long-term profit expectations often play a more important role. Therefore, in regulating the economy through the level of investment, the same effectiveness cannot be ascribed to monetary policy as to fiscal policy.

2.5.3.3 Income or wage-price policy

In general, income or wage-price policy is used by the government as a means to achieve a balanced level of wages throughout the economy and also to control price levels in an attempt to stabilise the economy. It is a relatively new instrument of macroeconomic policy and is often regarded as complementary to other instruments. However, changes in either wage or price policies usually have greater implications for the construction sector than other sectors of the economy.

As the construction process is labour-intensive, wage policy is of direct concern to the construction industry. Besides setting the level of wages which influences the cost of construction in the short-term, it also affects the industry in the long-term as wage reform helps to induce a more appropriate labour supply and structure. Turin (1969) highlighted the significance of wages in the construction industry since it has to compete with other sectors of the
economy for skilled workers. He found that wages in the construction industry tend to be higher than those in manufacturing in more developed countries as there is a greater need to attract workers to construction jobs where working conditions are particularly hard and hazardous.

Price policy affects the construction industry both directly and indirectly. Being largely an assembly industry, assembling on site the products of other industries, it has to purchase most of its raw materials and services inputs externally. The cost of construction is directly affected by any price change policies involving these inputs, which ultimately affects the level of demand for construction as well. Indirectly, the general price level and stability in the economy have a strong impact on the willingness and ability of households and firms to spend on expensive investment goods such as dwellings and factory buildings.

2.5.3.4 Balance of payments policy

Balance of payments policy is concerned with the management of the exchange rate and free-trade barriers so as to direct trade flows. Among all the policy instruments, a change in the balance of payments policy has relatively lesser significance for the construction industry. However, the extent of its influence varies from one country to another, depending on the construction industry's level of reliance on foreign trade.

In some countries, the construction industry may be a significant importer of raw materials due to a lack of natural resources. Hence, it is particularly sensitive to changes in the balance of payments especially when such changes lead to movement in the exchange rate, which has a direct impact on overall construction cost. Any free-trade barriers such as import tariffs and quotas also have direct implications for the supply and price of such raw materials. Moreover, much plant used by contractors is also imported and the cost of purchasing and renting them rises when the exchange rate moves downwards.

Construction firms in some countries may also be exporting their services overseas. In this case, they are also significantly affected by variations in the exchange rate. Most overseas contracts are negotiated in foreign currencies, so that a change in the exchange rate directly affects their profit margins and also threatens their international competitiveness.

In addition, policy changes that are made in the first instance to influence external trade and
capital movements may also lead to adjustments in the domestic economy and so produce an indirect impact on the derived demand for construction.

2.5.4 Shortcomings of using the construction industry as an economic regulator

With regard to the considerable fluctuations that levels of demand for construction is subjected to, Hillebrandt (1984:7) remarked that "at times government has reduced these fluctuations in its management of the economy but has also often exacerbated it." Ball (1988) also agrees that fluctuations are often exacerbated by government manipulation, designed to use construction as an economic regulator. Earlier, Stone (1983) already noted the undesirable effects of changes in the level of demand on the construction industry when the government uses the industry as a regulator. He stressed that the greater the difference in demand between the boom and bust period and the more frequent they are, the less well-adapted the construction and material producing industries tend to become to meet higher levels of demand. Tender prices also tend to be higher and the rate of completion tends to be slower. Besides, unstable demand is clearly a disadvantage to the industry and to its clients. Wong (1985) found that fluctuating levels of demand has detrimental effects on the performance and operation of construction firms, especially on their production efficiency. Competition for construction work and resources, profitability levels, production volumes, construction delays and quality standards were also cited as some of the effects of demand fluctuations (Hindle, 1993b). Considerable waste of resources and inefficiency in the industry in the long run will lead towards a general decline. On the contrary, stability in demand usually enhances an appropriate level of supply with the promotion of efficiency and competitive prices.

Another problem of using the construction industry as a regulator is that it becomes an ineffective tool because it is too slow to act (Hillebrandt, 1984). The construction process is long and it can be several years between the conception and completion of a building project. A change in value of orders would take several years to have its full effect on the level of current work. Owing to the time scale of the industry's operations, effective intervention needs to be made by the government long before the correction to the economy is required. This would require the government to recognise the way economic situations are developing several years ahead. At the same time, the problem of timing is also difficult. Contracts cannot be suspended immediately and the current stage of work must be brought to an orderly end or the ultimate costs may be raised considerably. Besides, to stop the construction process once it has commenced is
disruptive, inefficient and costly to the client. If construction work is postponed, much of the planning and design work may need to be revised for later use and land may be lying idle. All these factors will again result in the inefficient use of resources in the construction industry, and in the long run may lead to more adverse consequences for the whole economy.

2.6 The role of the construction industry in economic development and growth

2.6.1 Construction and socio-economic development

Socio-economic development has been defined by Ofori (1990:90) as a process which "involves expanding the productive capacity of the national economy to increase the supply, or improve the quality, of the goods and services at the disposal of the citizens." The construction industry has often been cited as one of the main contributors to socio-economic development, owing to its significant contribution to GDP, its employment-generating potential, its inherent role as an economic regulator, and its strong inter-sectoral linkages.

Generally, studies of the role of construction in economic development have been based upon the vital linkages between the construction industry and the national economy. The World Bank (1984) noted the construction industry's extensive inter-sectoral linkages and high value added-to-output ratio, and regarded them as impetus for growth and development throughout the economy. The interdependence between construction and other sectors of the economy was further examined and confirmed by Bon (1988). Park (1989), in his study of both developing and developed countries in the Pacific Basin, attributed the significant multiplier effects generated by the construction industry to its many linkages with the other sectors of the economy.

The interdependence between construction and socio-economic development was highlighted by Ofori (1990). He emphasised that although the important role played by the construction industry in the economic development process is evident in a typical construction cycle, the success of development also leads to an increase in disposable income, generating demand for more construction activities.

The role of construction among countries of different stages of economic development is clearly distinguished by several writers. Strassman (1970) noted that in countries with higher average
income level, which signifies higher economic development, there is greater contribution of construction to GNP and total employment. Turin (1969) also observed differences between developing countries and industrialised countries in respect to: contribution to GDP in terms of value-added in construction; contribution to GDP in terms of capital formation in construction; the amount of labour force employed in construction; the amount of input purchases from other sectors of the economy for construction; and the relative share of different types of construction such as dwellings and civil engineering work. His findings were updated by subsequent studies (World Bank, 1984; Edmonds and Miles, 1984; Wells, 1985; and Low and Leong, 1992) which indicated similar trends. Most recently, Ofori (1988) compared Strassman's and Turin's findings with developments within the economy and the construction industry of Singapore during her course of national socio-economic development, advancing from a developing country to a newly industrialising one. He found that most of the hypotheses on the role of construction in development have been supported by the experience of Singapore. He concluded that the construction industry had established the infrastructure required for sustained socio-economic development while being a major contributor to overall economic growth in Singapore. In an earlier report by the United Nations Centre for Human Settlements (1987), Singapore was cited as the classic case of a country that chose construction as a lead sector for its economic development. It was also highlighted that, in general, countries that stimulate construction activities and make high allocations to settlement development and housing programmes achieve fast rates of economic growth, low rates of unemployment and an equitable income distribution. The major role of construction in the economic development of Singapore is closely examined in Section 2.7.

2.6.2 Construction and long-term economic growth

The construction industry's major role in the national economy has created an interdependence between construction and long-term economic growth. The construction industry is the main sector of investment which contributes significantly to economic growth. Drewer (1980) refers construction to "growth-initiating" and "growth-dependent", while Ofori (1990) regards construction as the "engine of economic growth". Ball and Wood (1994b) have provided evidence of a long-run steady state relationship between building investment and economic growth for the UK from the middle of the twentieth century to the present day. However, factors and conditions of long-term economic growth have serious implications for the construction industry. Stone (1983) cited population size, size and condition of built stock, technological
change, changing life styles, and long and short term economic conditions as some of the factors that can influence demand for development and construction. For instance, in Germany, poor economic performance, rising unemployment, high nominal interest rates and inflation, and an anticipated decline in the population were cited as major factors that caused the slump in housing construction (Severson, 1992).

In essence, all construction items, except for the purpose of defence, are regarded as investments by economic accounting definition. This suggests that they contribute to the accumulation of capital, which is one of the prerequisites for economic growth and an improved standard of living (Andersen and Pedersen, 1976). Economic growth and social equality presuppose more construction and more construction contributes to growth. Construction and other investments can therefore be used as a means to stimulate growth and welfare. In a study by Massood (1987), the relationship between economic growth and construction trends in 100 countries was used to develop a simulation model, linking annual economic growth to the annual levels of investment in construction. The model was subsequently used to simulate effects of varying levels of construction investment on future economic growth in low, middle and high income countries.

Generally, construction activities are carried out in the light of long-term national objectives. Any prognosis of future economic and social trends of a country may be regarded as useful as it is likely to affect future construction activity, which in turn has direct consequences for the economy. The Economic Commission for Europe (ECE) Secretariat (1976) conducted a study to explore long-term future developments in Europe and discuss their impact on the construction sector. The factors and conditions identified as likely to play important roles in future economic development are summarised below. Implications for future levels of construction activity are also given for each factor.

a) Demographic trends and projections

Long-term population changes will be among the major factors affecting countries in the ECE region in the future. It was found that demographic trends for Europe and the ECE region as a whole are resulting in a significant decrease in their respective shares of world population. The combination of declining fertility rates and a reduction in total longevity improvements is projected to lead to a slowing down of natural rates of population increase. The age structure
will also be changing quite substantially in the low fertility countries, with an increasing ratio of old to young.

The impact on the construction sector with regard to changing demographic trends will be strong. With a decreasing trend in population, demand for housing construction will be mainly affected. The changing age structure of the labour force also means that there will be a decline in the supply of young labour. This may have serious implications for the future construction sector, of which its activities are predominantly labour-intensive, relying on young and able workers. Besides, a major shift in public expenditure towards social and economic welfare for the old is also anticipated. This would imply that government's spending on buildings and infrastructures will have to be lessened.

b) Supply of basic products and energy

Since the oil crises in the 1970s, it was found that prospects of assured supply patterns of basic products and energy have been greatly undermined, especially in the ECE regions. High-priced energy over the long term may be expected to generate major international economic consequences, among them a restructuring of world trade flows, institutional arrangements to handle the recycling of surplus oil earnings as well as to ease the financial difficulties of energy-importing countries particularly hard-hit by high energy costs, and measures to re-establish balance-of-payments equilibrium. In the medium to long term, all countries of the region may be expected to pursue a systematic investment policy with respect to basic products and energy in order to diversify their supply sources and to apply resource-saving technology. Policies will be designed to achieve both demand reductions and supply increases in basic products and energy.

The main implication for the construction sector in this respect is that design changes, improved insulation and new construction methods aimed at conserving energy and basic products utilisation may be expected. Future construction costs may also increase due to higher cost of basic products and energy. This will again directly affect the level of demand for construction.

c) Science and technology

With regard to an anticipated future shortage of basic products and energy, governments are likely to increase their research and development effort on a large scale. Scientific and technical
co-operation within the ECE region would also seem likely to increase both in developing new sources of energy and basic products, and in adapting technology to the utilisation of new basic products and energy forms which will substitute for scarce products. A further area of interest involves the development of resource-saving technology.

On the whole, the construction sector will be influenced or even directed to embark on more research and development projects. A radical change in the use of material inputs and construction methods may be expected. This may have implications for construction costs and thus demand again.

d) Environment

National efforts and international co-operation in overcoming water and air pollution, and in protecting the seas and outer space may be expected to expand. This increasingly active role of the ECE governments in the area of pollution abatement and control, as well as overall environmental management may be attributed to the growing consciousness that the environment should be seen as a unique public good. However, it was noted that internalising the costs of environmental preservation will not be a simple process. There will be economic costs with serious consequences for the rest of the economic system.

The implication for the construction sector will be greater environmental awareness in carrying out all its future construction activities. Particular emphasis may be placed on the use of material inputs, for example, utilising replaceable natural resources, reducing material and energy wastages, and using environmentally friendly products. Bye-laws regulating noise and air pollution will become more stringent. The overall aim is to encourage environmentally sustainable construction.

2.7 A review of the relationship between the construction industry and the national economy of Singapore

The Singapore economy experienced four development phases since it opted for full independence in 1965. Over the same period, the construction industry also undergone different stages of growth and decline. Table 2.2 provides a historical account of both the national economy and the construction industry in Singapore, from 1965 to the early 1990s, in four main
development phases.

The relationship between the construction industry and the national economy in Singapore was closely examined by Ofori (1988). His main objective was to determine the role of the construction industry in Singapore's economy during the post-independence years (1960-1986), in which the nation advanced from a developing country to a newly industrialising one. The highlights of his findings are given below.

1) Construction has played an important role in Singapore's socio-economic development. The sector contributed between 3.5 and 8.5 per cent of GDP over the period under review. Capital formation was between 30.5 and 59.7 percent. During the construction boom in the early 1980s, value added in construction grew at a compounded annual rate of 13 per cent compared with the corresponding rate of 9 percent for the economy as a whole.

2) The construction industry was the fastest growing sector of the economy in the early post-self-government years of infrastructural development (1960-1965). As the rapid industrialisation programme gained momentum, construction lost this leading role to manufacturing after the mid-1960s. Between 1979 and 1984, the industry again expanded at a higher rate than any other sector of the economy. The decline of the role of construction in the economy since 1985 occurred after the progression of the nation into middle-income status. These events were found to correspond with Strassman's (1970) observations.

3) There was also a pattern of change in the mix of construction output over the period under consideration. In the early post-independence years, infrastructural and housing development dominated output. After 1967 and until 1984, construction output for non-residential building gradually increased while residential building slowly declined. This is the result of rapid industrialisation which took place from the mid-1960s.

4) In 1983, it was found that with every $100 of construction output, $146 worth of output in the wider economy was generated, mainly through spendings on inputs from other sectors, imported materials and labour. About 96 per cent of the industry's
Table 2.2 Singapore’s National Economy and Construction Industry between 1965 and the early 1990s.

<table>
<thead>
<tr>
<th>Period</th>
<th>The National Economy</th>
<th>The Construction Industry</th>
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<tbody>
<tr>
<td>Phase One</td>
<td>General trend: Rapid growth of 12.7 % per annum.</td>
<td>Experienced negative growth in 1966.</td>
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<td></td>
<td>Strong growth in world trade due to trade liberalisation.</td>
<td>Growth declined in 1973 owing to world recession.</td>
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<tr>
<td>(1974 to 1977)</td>
<td>Slow growth mainly caused by turbulent external conditions, e.g. oil crisis.</td>
<td>Sharp decline in 1977 due to depression in the property market.</td>
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<tr>
<td>Phase Three</td>
<td>General trend: Moderate growth of 8.7 % per annum.</td>
<td>Sharp decline continued into 1978.</td>
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<td>It was the fastest growing sector of the whole economy.</td>
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<tr>
<td>Phase Four</td>
<td>General trend: Very slow growth of 2.9 % per annum until 1987, followed by slow growth.</td>
<td>Sharp decline again in 1985 owing to property glut and significant contraction in the public housing programme.</td>
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output was used as final investment goods. These confirmed the industry's importance as the creator of the physical facilities required for economic activity, its direct contribution to the economy, its inter-sectoral linkages and its employment-generating potential.

5) Specifically, it was observed that the industry contributed about a third of the rate of increase in economic growth in a typical year between 1978 and 1984, that is, during the period of the construction boom. It was also responsible for much of the decline in 1985, and up to 1989, the continuing decline in its activity hampered the expansion of the economy.

6) It was concluded that the construction industry has played an important role in the economy of Singapore. It established the infrastructure required for sustained socio-economic development while being a major contributor to overall economic growth in most years.

2.8 Chapter summary

In this chapter, a macroeconomic definition of the construction industry was proposed in Section 2.2. It serves as a supplement to existing definitions which have mainly described the construction industry only in terms of the activities undertaken by it. The idea is to broaden the scope of existing definitions in order to include the construction industry's vital role as a sector of the economy and its interrelationship with other sectors. The contribution of the construction industry to the whole economy remains too significant to be ignored. In addition, the section also defined the four main objectives and instruments of macroeconomic policy, which are central to the workings of a national economy.

The nature of building cycles and their relationship with business cycles were examined in Section 2.3. The nature of a building cycle was outlined with reference to the general economic environment since it was explained that the level of demand for construction is affected by an increase or decrease in economic activity. The close interaction between building and business cycles was substantiated with evidence from past empirical studies.
Next, the chapter progressed to a close examination of the relationship between the construction industry and the national economy. The relationship was explored with regard to three main aspects; the construction industry's role in the national economic system, macroeconomic policy, and economic development and growth.

Section 2.4 detailed the first aspect of the relationship. Construction was related to some vital macroeconomic measures. The significant contribution of construction to national output, and the major role played by construction in national consumption and production were the two main areas covered. Then, the context of the construction industry in the national economy was examined with respect to a conceptual framework. Eventually, the interdependence between the construction sector and other sectors of the economy was discussed.

The second aspect of the relationship was elaborated in Section 2.5. A general discussion of the government's need to adopt economic policies to regulate the economy and its common practice of using the construction industry as the regulator was first carried out. The section then proceeded to discuss the significance of different policy instruments to the construction industry and the impact of a change in each of them on the level of construction demand. Despite being a common practice, some shortcomings of using the construction industry as an economic regulator were also highlighted.

In Section 2.6, the third aspect of the relationship was covered. The issue of the role of construction in socio-economic development was first discussed. The areas highlighted include the construction industry's vital inter-sectoral linkages, interdependence between the construction and socio-economic development, and the distinct role played by construction in different stages of economic development of a country. Next, the interdependence between construction and long-term economic growth was examined. Construction, which essentially produces investment goods, was highlighted as an important factor for long-term economic growth. On the other hand, long-term national objectives also have a strong impact on future levels of construction demand. Several factors and conditions for long-term economic growth were reviewed and their impact on the construction industry was duly discussed.

Finally, Section 2.7 reviewed the relationship between the construction industry and the national economy in Singapore. Singapore was chosen, in particular, for the review because it has been cited as a classic case of a country that chose construction as a lead sector for its economic
development. In essence, the review confirmed the important role played by the construction industry in the national economy in areas such as socio-economic development and overall economic growth.
3.1 Introduction

Chapter 3 provides a theoretical review of construction demand, which is a key measure of construction industry performance and the main focus of interest of this study. In essence, knowledge of future levels of demand for construction is vital to the general well-being of both the construction industry and the national economy.

The chapter begins by defining construction demand in Section 3.2. Demand is first defined in general economic terms, and then in relation to construction. Definitions are also proposed for different types of building construction demand.

Section 3.3 discusses the nature of construction demand, focusing on the significance of "derived" demand and the problem of uncertainties in demand. As the nature of demand is different for various types of construction, Section 3.4 elaborates on the need to disaggregate construction and examines the different ways of classifying them.

Construction output and demand are closely related. Being key indicators of the construction industry, they are examined in terms of their role as measures of performance. Section 3.5 begins with a general discussion of the need to measure performance in the construction industry. Several reasons are given to justify the need. It is followed by a description of the basic methods of measurement. They include numbers, gross floor area, index numbers, and volumes and values. The problems arising from the use of these methods are also discussed. Finally, several key measures of output and demand are given and described. The basic information provided for each measure includes the scope, significance and interpretation.

3.2 Definition

In general economic terms, demand is defined as the requirement for goods and services that the consumer is able and willing to pay for. However, according to Hillebrandt (1984), this
definition does not fully explain the demand for construction as need should be the basis for generating such demand. The unique characteristics of construction goods, especially their massive size and high cost, their long life and investment nature, would imply that buildings and works are demanded only when there is a need for them. She defines need for buildings and works as the difference between an accepted standard of provision and the extent to which the building stock reaches this standard. By putting the two definitions together, she derived five major requirements that must be favourable before demand for construction can be created. They are:

(a) there is a user or potential user for the building or works in the short run or in the long run;
(b) some person or organisation is prepared to own the building or works;
(c) a person or organisation is prepared to provide finance for the construction of the building or works and for its ultimate ownership;
(d) some person or organisation is prepared to initiate the process; and
(e) the environment and external conditions in which the above requirements operate are favourable.

The determination of demand for construction is further complicated by a disaggregation of construction. In general, building construction can be classified into residential, industrial and commercial types. The determinants of demand for each type are inevitably different as they serve distinct purposes. Based on the determinants of demand, the following definitions are proposed to distinguish the demand for residential, industrial and commercial building construction.

"Demand for residential construction may be defined as the requirement for buildings to serve the need for direct consumption."

"Demand for industrial construction may be defined as the requirement for buildings to serve the need for producing some other goods and services."

"Demand for commercial construction may defined as the requirement for buildings to serve the need for accommodating business activities."
3.3 Nature of construction demand

The nature of demand on the construction industry is often fraught with uncertainties, leading to pronounced fluctuations in its trend. Briscoe (1988) attributes the fluctuations in demand to changes in the economy and the government's management of it. Hillebrandt (1984) explains further that the role of government influence, together with the link between investment and demand, means that demand tends to fluctuate particularly according to the state of the economy, and the social and economic policies of the government, with the consequent effects on construction.

Cyclical changes in demand produce many difficult problems for the industry at all levels, particularly construction firms and their workforce. Although it is believed that the varying levels of demand might encourage construction firms to be efficient at all times by cutting down costs in order to remain competitive, failure of them to anticipate significant changes in demand would almost certainly affect profitability, and perhaps their survival. Large firms continue to grow by switching resources between different types of construction while smaller ones face the risk of bankruptcy and liquidation owing to strong variations in both turnover and profitability.

Generally speaking, demand on the construction industry is for investment goods, in the sense that they are required not for their own sake but for:

a) carrying out manufacturing and business activities (such as factory and office buildings);
b) providing social and community services (such as churches and hospitals); and
c) providing direct enjoyment and store of value (such as housing).

This implies that most of its products will be required only if certain other factors are favourable, for example, the expected sales of the goods which the factory would produce; the economic climate in which government takes decisions about the level of social services; and the availability of mortgages for house purchase. For all these reasons, the moment of investment is a matter of choice and will be determined by a number of factors over which the construction industry has no control. Besides, construction products are very durable and their stock is large in relation to the annual production. Small fluctuations in the demand for the stock of buildings and works will have very large repercussions on the demand for new buildings and works created
by the industry. Moreover, the industry is largely unable to stock its products and thus cannot meet future demand out of stock.

Ofori (1990) attributes uncertainties in demand on the construction industry to the characteristics of construction goods. He described them as:

a) not homogeneous, each can be considered unique;
b) large, indivisible and very expensive, and hence the market has few buyers and sellers;
c) immobile, hence the supply cannot be transferred to an area of high demand, and demand is also relatively location specific;
d) subject to a wide range of external (political, sociological, cultural and economic) influences; and
e) susceptible to the actions of the government, which is a major client.

The uncertain nature of demand on the construction industry has prompted many studies looking into ways of predicting future levels of demand for construction. Owing to the different purposes for which each of the main types of construction is produced, the demand for them is subject to the influence of different factors. The studies are mainly based on disaggregated construction where different techniques are applied in order to assess levels of demand for each type. Hillebrandt (1984), however, highlighted that the general economic situation and expectations about its future changes is a common aspect of the environment that affects all construction demand. Massood (1987), in his study, also found that the size and growth of construction demand is strongly related to the size and growth of the total economy.

3.4 Classification of construction

Construction goods have been generally described by Ofori (1990:110) as "non-homogeneous, each can be considered unique". Thus, the construction industry produces a wide variety of different types of construction. In order to treat them separately, based on their individual unique characteristics, construction is disaggregated mainly according to the purpose that they were built for. For national accounting purposes, construction is also disaggregated to allow for statistical distinction. This generally applies to the compilation of national statistics for the construction
industry.

The unique characteristics of different types of construction have been recognised by several writers. Classification of construction is mainly adopted to carry out studies related to construction demand and output. In the study of construction demand, different techniques are required to assess the levels of demand for each type as differing factors influence the demand for different types of construction. Although there is no universal approach, Turin (1969) suggested several ways of classifying construction and they are:

1) new work, and maintenance and repairs;
2) residential building, non-residential building and other construction works;
3) public sector and private sector works; and
4) modern and traditional categories.

Whilst each of these classifications is generally acceptable, a combination of two or more of them have been more commonly adopted. Shutt (1982) and Raftery (1991) classified construction as: public-sector housing; public-sector non-housing; private-sector industrial and commercial work; and rehabilitation, improvement, repair and maintenance. Hillebrandt (1985), Briscoe (1988) and Ofori (1990) adopts the classification comprising: housing; industrial and commercial buildings; public non-housing or social-type construction; and repair and maintenance. New construction work has been broadly classified as: private housing; commercial and industrial development; and public development by Cassimatis (1969) and Stone (1983). Only Lange and Mills (1979), and Tang et al. (1990) have classified construction following one of those proposed by Turin (1969), which is: residential buildings; non-residential buildings; and other works.

In general, classification of construction largely depends on sufficient statistics available to provide a detailed breakdown of construction according to the categories adopted. Knowledge of the relative importance of the various categories of construction is a prerequisite for formulating policies for the construction industry in any country, particularly developing countries (Turin, 1969).
3.5 Measures of construction output and demand

Regarding construction demand, Hillebrandt (1984) noted that although there are some indicators of demand, there are no statistics of demand, only of output. Thus, although the concept is clear, there are no hard data to evaluate the level of demand separately from output. Besides, output and demand are the two most important construction measures: description of one would inevitably involve the other. Hence, the following is a discussion of the role of both output and demand as key performance indicators of the construction industry.

3.5.1 The need for measurement

Hillebrant (1984:4) highlighted that "the construction industry, through the products that it creates, has a greater effect on the environment than any other industry". Therefore, it is necessary to measure the performance of the construction industry in order:

1) to ascertain its level of production over time so as to determine its economic impact on the general economy;
2) to assess the performance of other sectors of the economy owing to their close linkages with the construction industry;
3) to facilitate comparison with the construction industries of other countries; and
4) to forecast its future performance based on current and past trends so as to assist the construction industry in anticipating any future changes or constraints.

3.5.2 Basic methods of measurement

The construction industry produces a variety of different types of buildings and works that are of different sizes and value, and adopting different methods of construction. It also employs a wide range of manpower and professionals of which the numbers and mix varies with time. Hence, the complex nature of the industry renders the adoption of a single method of measuring its performance impossible. The following are several basic methods used for measuring performance.
1) Number

In terms of measuring the industry's output to assess its performance, this method of measurement is the simplest as it only involves counting the number of items constructed for each type of construction within a chosen time period. However, owing to its simplicity, vital information is left out such as the size, value and quality of the projects. By looking at numbers alone, the performance of the industry may be misjudged. For example, it would be misleading to base the industry's performance solely on the number of projects undertaken. The total contract value may be high even though the number of projects is small. Effectively, the high project value contributes more to the GDP, indicating higher value added in construction. Ofori (1990) also views numbers as an impractical system for measuring construction output owing to the wide variety of types of construction and their different sizes and methods of construction. However, when assessing performance based on the amount of manpower employed, the use of numbers is a common method of measurement. A large number of workforce employed in construction usually implies a healthy and booming industry.

2) Gross floor area

When measuring output, gross floor area is regarded as a more realistic measure because it identifies a significant quantifiable attribute of each type of construction (Ofori, 1990). Specifically, it gives an idea of the size or magnitude of the items of construction. However, when comparison between different types of construction is required, this measure raises some problems since a square metre of floor area of a factory cannot be compared with that of a school. In fact, two buildings of the same type are seldom wholly comparable. Similarly, this measure does not provide information on the materials used and methods of construction or the overall height and individual storey heights.

3) Index number

This is a relative measure and is expressed as a percentage of a single base figure. It is commonly used to measure changes in the costs or prices of construction output over time, with reference to a base year figure. The problems associated with this measure again arises from the extremely varied nature of the work carried out by the construction industry. Since each project tends to be unique, from the point of view of measuring changes in costs over time, there is no
single standard of comparison. New construction projects vary not only in type but also in size, design, specification, complexity and methods of construction. Even similar projects vary according to differences in site conditions with a consequential influence on costs of construction. Besides, the considerable period of time that construction projects often take from start to finish also means that costs may be measured at different stages of the process. Clearly, measurements which relate to different stages may be expected to differ and likewise the rates of change over time of such measurements may not be equivalent. In response to these problems, various methods of constructing indices have been employed and a variety of different index series have been devised. Often, two or more indices are combined to form one composite index. The most straightforward way of combining indices is to calculate a weighted average of the indices used.

4) Volume and value

These are two commonly used monetary measures of construction output. Ofori (1990) regards money as the most convenient measure of construction output, one that provides a simple means of comparison. Effectively, a higher volume or value of construction output implies better performance. A direct relationship can also be implied between projects attributes such as quality, size, construction method and monetary measures. For instance, a larger project using higher quality materials and adopting more advanced method of construction would incur higher costs. However, there is one main problem associated with using monetary measures, that is, the effects of inflation. In general, costs are influenced by the level of prices in a country's economy, the industry's efficiency and the difficulties in its operating environment. These factors not only change over time within each country, but are also different among countries. They hinder comparisons of output in the same country over time, as well as that among different countries.

In view of this problem, the concept of volume and value is developed. Volume is a measure of output in constant price while value is that of output in actual market price (The Economist, 1994). Therefore, a volume indicator provides information about changes in volumes and not prices, and value is volume multiplied by market price. In practice, a deflator is normally used to adjust data on each sector of the economy to allow for the effect of inflation. However, some researchers (Dacy, 1965; Rosefield and Mills, 1979; and Stokes, 1981) noted that official deflator indices do not entirely capture qualitative changes in output, and tend to under-estimate construction output, and hence, productivity. Besides, within a country, output in monetary terms would be influenced by changing mixes of demand, forms of construction, structure of
workload, levels of capital utilisation and other related factors.

Despite these shortcomings, monetary measures are still widely adopted and are often supplemented with data provided in other forms, such as floor areas of buildings, number of rooms for hotels, number of beds for hospitals, lengths of roads and others.

3.5.3 Measures of output

In general, construction output is measured by obtaining returns from contractors and direct labour organisations and is defined as the value of work done during a specified period (Fleming, 1986). Ofori (1990) elaborates that information on output covers the industry's production within particular periods, on both completed and uncompleted projects of all kinds and on both new work and repair and maintenance, and relate to construction activity within the country concerned, whether by local or foreign enterprises. Construction output figures generally provide vital information about the industry. They have been found to be one of the most frequently referred to categories of construction statistics among British private construction firms (Ministry of Public Building and Works, 1968). The following are some of the measures of construction output.

3.5.3.1 Gross output

Ofori (1990:34) defines gross output as "a measure of the total production of the construction industry and includes items other than physical buildings and works, as well as the value of materials and other inputs obtained from other sectors of the economy." It is, therefore, the sum of: (1) the total value of new work, repairs and maintenance of both completed and uncompleted projects; (2) the value of sales of other products of construction enterprises; (3) the sales value of goods sold in the same condition as purchased by construction enterprises; and (4) rents received on the buildings, machinery and equipment owned by the enterprises including imputed rent for owner-occupied premises.

In terms of assessing the performance of the construction industry, gross output is highly significant. Ofori (1990) regards this measure as the most comprehensive indicator of the amount of work a particular country's construction industry can undertake in a given period. Therefore, a high gross output generally indicates that the industry is performing well. However,
he cautioned that a high output may also reflect the difficulties of construction in that country, the quality of materials used or the level of quality of workmanship achieved. Many local factors, such as, climate, topography, statutory and regulatory requirements, can affect the cost of construction to varying degrees in different parts of a country and also from one country to another. Moreover, a few projects of high cost, such as an airport, a mass rapid transit system or a national programme involving the construction of a large number of health centres or schools may distort the picture of overall construction output for some time. Nevertheless, gross output is still the best performance indicator of the construction industry as a whole.

Fleming (1986) stresses the principle for measuring output as the value of work done in a specified period as opposed to the value of contracts completed. In Britain, the Department of the Environment (DoE) output statistics were compiled based on this principle until 1979. Contractors were asked to return the amount chargeable to customers for work done together with the value of work done on their own initiative, such as the building of dwellings or offices for eventual sale or lease, and work done by their own operatives on the construction and maintenance of their own premises. The practice of requiring a return of the value of work done each quarter required the partial valuation of projects under construction. In principle, this should present no difficulty, especially because in most cases in Britain, contractors receive regular progress payments during the course of a contract based upon valuation certificates. Valuations are based on measuring the work completed to date and a certificate is issued showing the amounts due when agreement is reached between the client's consulting architect or engineer and the contractor. Since the fourth quarter of 1979, an important development in collection method was introduced in which returns are sought for individual projects rather than for work done in the aggregate. This has allowed a breakdown by type of work to be made in much greater detail than hitherto and also permits an analysis by regional location of the work in Britain. This new collection method is known as the project-based enquiry system. A full description of this system is given by Wheatcroft (1981).

Some examples of the available series of gross output are:

- Value of construction output by type of work;
- Volume of construction output by type of work;
- Volume of construction output: at constant prices;
- Value of construction output by contractors; and
- Value of progress payments certified.

Monetary measures of gross output are often supplemented with non-monetary measures which provide additional information on building developments. The available series are:

- Number of developments commenced by type of building and sector;
- Gross floor area of developments commenced by type of building and sector;
- Number of developments completed by type of building and sector; and
- Gross floor area of developments completed by type of building and sector.

When disaggregated by type of building, measures of developments commenced are also known as housing starts, educational building starts, industrial buildings starts, and so on. These series were also found to be popular among British private construction firms (Ministry of Public Building and Works 1968).

3.5.3.2 Fixed capital formation

This is another measure of construction output and is defined by Ofori (1990:34) as "the total value of all new construction and all capital alterations or extensions that significantly improve upon the utility or extend the life of the building or works (and therefore add to the productive capacity of the economy)." Therefore, repair and maintenance merely to keep buildings and works in a presentable or safe condition are not included. He emphasised that capital formation in construction should not be confused with the industry's investment in fixed assets such as plant and equipment, which is sometimes included among data on the industry, and referred to as "capital formation by the construction industry" or "gross additions to fixed assets of construction enterprises". He also highlighted that the main difference between gross construction output and capital formation in construction is that the former includes routine repair and maintenance and sale of items other than construction by the enterprises but the latter does not. Thus, the value of gross output may be considerably higher than capital formation. Regarding the measurement of performance of the industry, he considers this measure as the next best indicator of the size of the industry. At the same time, figures on capital formation by the construction industry also indicate the sector's preparedness to undertake its workload.
Fleming (1986:136) defines fixed capital formation as "investment in physical productive assets that yield a continuous service beyond the period of account in which they are purchased". He also distinguished fixed capital formation from gross output by regarding the former as capital expenditure statistics. He considers all expenditure on new construction work as capital investment, with the exception of housing which is regarded as consumption expenditure. Hence, statistics about investment, broken down by type of asset, would provide an important additional source of information about construction activity. In his view, investment in buildings and works is measured at the purchasing end of the transaction in terms of the cost to the purchaser, largely independent of output statistics which are measured from the opposite (supply) side of the transaction on the basis of returns provided by producers or contractors of the value of work done. When fixed capital formation statistics are regarded as expenditure series, they are distinguished from output data. He also made a distinction between net and gross domestic capital formation. The term "gross" signifies that no deduction is made for wear and tear, obsolescence and accidental damage. The term "domestic" denotes that the statistics are confined to assets located in that country.

Some examples of the available series of fixed capital formation are:

- Value of gross domestic fixed capital formation (GDFCF): at current prices;
- Volume of gross domestic fixed capital formation (GDFCF): at constant prices;
- Volume of capital expenditure on construction by sector: at constant prices;
- Value of capital expenditure on construction by sector: at current prices; and
- Estimated value of capital formation in stocks and works in progress for construction.

3.5.3.3 Value added

Value added in construction is another measure of the value of the construction industry's actual production or output. In general, the concept of value added is used to assess the relative importance, by comparing the relative sizes, of the various sectors of a country's economy. It measures each sector's contribution to the economy. Therefore, value added in construction is often referred to as the contribution of the construction industry to GDP. Value added in construction, or net output, is defined by the Department of International Economic and Social Affairs (1988) as "the gross output at producer's prices less the value of all the industry's current purchases from other enterprises at purchaser's prices, that is, (1) value of materials and
components consumed; (2) cost of hiring plant; (3) cost of goods sold in the same condition as purchased; (4) legal and professional fees; and (5) payments made for repair and maintenance undertaken by others on the construction firm's own assets". Effectively, it comprises the following (Turin, 1973):

- salaries and wages of employees;
- interest on borrowed capital;
- net rent (i.e. the difference between the rent paid and that received by the enterprises);
- profit; and
- allowance for depreciation.

The significance of this measure is that it expresses value added in construction as a percentage of GDP, which is the appropriate means of indicating the role of the industry in the national economy. It is particularly useful when the performance of the construction industry is to be assessed against other sectors of the economy. Some examples of the available series of value added in construction are:

- Value-added in construction as a percentage of GDP;
- Volume of value-added in construction: in constant prices;
- Value-added in construction: in current prices; and
- Percentage change in value-added in construction.

3.5.4 Measures of demand

Over considerable periods of time, the level of demand and the level of output have largely been more or less the same (Hillebrandt, 1984). Hence, several forward indicators of demand have been developed based on output data. In the survey conducted by the Ministry of Public Building and Works (1968), forward indicators of construction demand are also identified as one of the most frequently referred to construction statistics among private construction firms in Britain. The following are some forward indicators of demand.

3.5.4.1 Contractor's new orders (or value of contracts awarded)

This is the most important indicator in terms of reflecting the immediate forward load on the
construction industry. It is, therefore, often regarded as a vital forward indicator of construction demand, also giving an indication of future levels of output. However, it only provides a fairly short-term indicator because it represents contracts already awarded, and work on site on most contracts can generally be expected to start within a few months of the contract being signed. One limitation of the data as an indicator of demand or total future output levels is that it covers new work to be carried out by contractors only. This means that work done by direct labour organisations and that of repair and maintenance is not covered. Nevertheless, it does consider the major part of construction activity and is therefore still a valuable series.

Fleming (1986) also highlighted that the scope of this measure covers orders received by contractors only and for new work to be carried out in that country only. Work to be undertaken overseas is covered in a separate enquiry. He defined the term "new work" as in the case of output, to include such work as extensions, major alterations with improvements, site preparation and demolition except for housing, for which extensions, alterations, and conversions work is excluded. In the valuation of orders, the value of a new order will normally be explicit, being the price accepted by the client. Another aspect of valuation is that when the statistics are used for forecasting purposes, new orders will be transformed into output over a period of time. However, the value of a particular project on completion may not necessarily be the same as the original contract sum owing to variations in the contract and/or fluctuation clauses which allow the contractor to claim for increases in construction cost. As such, the value reported as new orders in the aggregate is generally regarded as being likely to understate the amount payable by the time the work has been completed, or the value of output in the aggregate. For this reason, certain compensating adjustments are made to the published series of output derived from this measure (Fleming, 1980).

With regard to reliability, Fleming (1986) comments that this measure is particularly valuable as an indicator of changes in the level of demand on the industry. He supported this comment with two reasons. First, unlike the value of construction output, a new order can be precisely defined at a point of time whilst the value of output, which inevitably has to be carried out over a period of time, will normally need to be based, at least in part, on estimates. Second, in relation to the method of collection of data on new orders, information has always been collected for the order as a whole, and not separately for such parts of it as are let under sub-contract. Therefore, the problem of ensuring full coverage by collecting information from sub-contractors as well as main contractors does not arise. By their very nature, statistics of new orders are likely to be
more reliable than those of output.

Some examples of the available series of contractors' new orders are:

- Value of contractors' new orders by type of work and sector: at current prices;
- Value of contract awarded by type of work and sector: at current prices;
- Index numbers of contractors' new orders by type of work and sector;
- Number and value of contractors' new orders by size; and
- Number and value of contractors' new orders by duration.

3.5.4.2 Developments granted planning approval or commenced

This indicator also provides a picture of likely short-term demand (Ofori, 1990). It is often broken down by type of building and the possible methods of measurement are by numbers and gross floor areas. In view of the demerits and limitations of these non-monetary measures, the compiled statistics often serve as supplements to monetary ones. Nonetheless, by themselves, they serve to provide an indication of identifiable physical achievements. Among other uses, they give clients and consultants an idea of current demand and future supply of the different types of building developments. The available series of this indicator are:

- Number of developments granted planning approval by type of building;
- Number of developments commenced;
- Gross floor area of developments granted planning approval by type of building; and
- Gross floor area of developments commenced.

3.5.4.3 Investment intentions surveys

Another relevant indicator of demand or future levels of output is the statistics compiled from investment intentions surveys. In Britain, there are three of such surveys, two of which are quantitative while one is qualitative.

i) Public expenditure plans

Plans for public expenditure are published by the British government annually. The DoE will
analyse the construction components of the plans and publish them independently to provide figures of planned capital expenditure on construction for some years ahead and actual outturn figures for some years past. These statistics are particularly valuable in covering the public sector comprehensively but it should be noted that, as the data refer to capital expenditure, only new construction work is covered; repairs and maintenance expenditure is excluded. In addition, the data will cover contracts already in progress as well as new contracts to be let. However, these figures are inevitably subject to changes in government policy.

ii) Department of Trade and Industry (DTI) survey of investment intentions

This survey is currently undertaken twice a year and provides estimates for up to two years ahead. The data obtained relate only to investment as a whole; they do not distinguish construction from other assets. However, the survey is worthy of note because construction constitutes a major part of total investment. A full description of the survey is given by Lund et al. (1976).

iii) Confederation British Industry (CBI) industrial trends survey

This is a qualitative survey in which member firms of the CBI in manufacturing industry are asked, among other things, whether they expect to authorise more, the same or less capital expenditure in the following 12 months than in the previous 12 months. Building expenditure is distinguished separately. General results, which are weighted to take account of the type of industry and the size of response, are then published.

3.5.4.4 Private architect's design work

Statistics of the value of private architects' design work for building also serve as forward indicators of demand. The Ministry of Public Building and Works (1968) found that among the various forward indicators of demand, the Royal Institute of British Architects (RIBA) series are the frequently used advance indicators. They essentially describe private architects' new commissions and work at working drawing stage. The two series are also analysed by type of building and by sector at both current and constant prices. The general limitation of these data is that they are subject to sampling error and are affected by the normal uncertainties of the estimation of values at early stages of the design process. The series available are:
- Value of architects' new commissions by type of building and sector; and
- Value of architects' work entering the production drawings stage by type of building and sector.

### 3.5.4.5 Output forecasts

Strictly speaking, output forecasts can also serve as relevant forward indicators of demand. There are many available output forecasts in the industry because of the many forecasting techniques available for both quantitative and qualitative methods. This makes comparison of different output forecasts difficult since each will have its own advantages and limitations. Selecting the best output forecasts is thus hindered by subjective factors. Regarding the reliability of these indicators, it is inevitably subjected to the level of accuracy of the output forecasts. In Britain alone, there are four available sources of construction output forecasts. They are:

- National Economic Development Organisation (NEDO) construction forecasts;
- National Council of Building Materials Producers (BMP) forecasts;
- National Institute of Economic and Social Research (NIESR) forecasts; and
- London Business School (LBS) forecasts (housing only).

### 3.6 Chapter summary

In this chapter, both theoretical and quantitative perspectives were adopted to discuss the nature and measures of construction demand. Theoretical aspects of the chapter comprised definitions of demand and description of its nature, while quantitative aspects included discussions on the methods of measurements and the different types of measures available.

Some definitions of demand for construction were given in Section 3.2. They were derived based upon the concept of need which helps to establish the determinants of demand. For instance, the need for direct consumption brings about the demand for housing construction, and the need for accommodating business activities generates demand for commercial building construction.

In Section 3.3, the nature of demand for construction was discussed with respect to its volatility. It was attributed to economic influence, government's management of demand, construction
being an investment good and several other distinct features of construction goods. The detrimental effects of fluctuating demand on construction firms were also highlighted.

Methods of classifying construction were discussed in Section 3.4. As the construction industry produces a wide variety of construction, there is a need to classify them into unique groups based on the purpose that they were built for. This was elaborated with respect to the different classification methods adopted by several writers.

Section 3.5 is a detailed examination of the measures of construction output and demand. First, the focus was on their role as key performance indicators of the construction industry. Section 3.5.1 considers the need to measure industry performance, which has direct implications for measuring output and demand. Several methods of measuring performance were then described in Section 3.5.2. The heterogeneous mixture of work in the construction industry and the adoption of different methods of construction to produce a variety of different types of buildings and works that are of different sizes and value resulted in the development of several ways of measuring performance such as, numbers, gross floor areas, index numbers, volumes and values. The merits and demerits of each method were also discussed.

Next, the focus was on examining a list of basic measures of output and demand in terms of their scope, significance and interpretation. In Section 3.5.3, the measures of construction output considered were gross output, fixed capital formation and value-added or net output. Gross output was regarded as the most comprehensive indicator of the amount of work that a particular country's construction industry can undertake in a given period. The use of the value-added measure is only significant when the performance of the construction industry is to be assessed against other sectors of the economy. The measure of fixed capital formation includes the total value of all new construction and all alteration work that significantly improves upon the utility or extend the life of the building or work. Several forward indicators of construction demand were then considered in Section 3.5.4. They included, contractors' new orders, developments granted planning approval or commenced, investment intentions surveys, private architects' design work, and output forecasts. These measures have been developed based on output data since there are no hard data on demand which can be used to evaluate the level of demand separately from output. Contractors' new orders, also known as value of contracts awarded, is the most important measure in terms of reflecting the immediate forward load on the construction industry.
CHAPTER 4

THEORY OF ECONOMIC INDICATORS

4.1 Introduction

Economic indicators are often used as statistical measures of the performance of the national economy. Their relations with the business cycle indicate their role as being the most relevant measures of economic activity. The objective of this chapter is to provide basic information on the nature, use and interpretation of the key economic indicators which are used to track the economy.

In Section 4.2, definitions of indicators, economic indicators and the business cycle are provided to show the linkages between them. Next, their purpose and uses are discussed in Section 4.3. The discussion focuses on some prevailing perceptions about statistics that are relevant to indicators and, more specifically, on the events that led to the development of economic indicators. The basic methods of interpreting economic indicators are examined in Section 4.4. They include: volume, value and price; index numbers; percentage changes; growth rates; moving averages; and seasonality.

Finally, Section 4.5 provides information pertaining to the scope, significance and interpretation of several major economic indicators. They are grouped under the main headings of: national output and growth; population and employment; government fiscal policies; national consumption; investment and savings; industry and commerce; trade and exchange rates; money and finance; and prices.

4.2 Definitions

A simple definition of an indicator is given by Hildebrand (1992:7) as:

"a measure that provides knowledge of a particular, unique classification of information that has predictive value."
In relation to statistics, Horn (1993:5) described indicators as:

"intermediaries that link statistical observations with social or other phenomena...they are metadata, that is, data describing other data;...indicators acquire meaning in their application; they bring amorphous statistics to life".

In the context of the business cycle, economic indicators are defined as:

"descriptive and anticipatory data used as tools for business conditions analysis and forecasting" (Zarnowitz, 1992:283).

In order to highlight the association between economic indicators and the business cycle, it is also necessary to define the business cycle. It is defined by Burns and Mitchell (1946:3) as:

"a type of fluctuation found in the aggregate economic activity of nations that organise their work mainly in business enterprises; a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximately their own".

There are several points worth examining in this definition. First, it is clear that the business cycle comprises only two phases; the expansionary and contractionary phases. Second, the business cycle is not limited to a single firm or industry, but is economywide, expected to show most clearly among aggregate indicators. Third, one cycle follows after another; they are marked by regularities and similar sequences of events. Fourth, cycles differ, however, in how long they last, so there is no regular periodicity. Fifth, time periods for a whole business cycle range from one to twelve years; there is no evidence of two or three mild cycles within each severe, longer cycle. Finally, the business cycle emphasizes co-movements as evidenced by the clustering of peaks and troughs in many economic series.
4.3 The purpose and use of economic indicators

According to Horn (1993), the whole concept of indicators is based on the role of statistics. In essence, statistics are used in the dual sense of numerical facts, which are the basic material for indicators, and of a methodology, which serves as a tool for the construction of indicators. He regarded statistics as the building blocks of indicators as they can be assembled in various ways for different indicative purposes. In this context, the general purpose and use of indicators can be discussed in relation to some prevailing perceptions about statistics that are relevant to indicators. In short, indicators are necessary because:

1) numbers hold a fascination of their own for many people: they become metaphors of phenomena, and they order people's thinking into a fixed frame that is seemingly objective in the rigour of its spacing;

2) there is a need to measure in order to cope with the environment, rhythm of nature and scarce resources: and

3) comparisons, expressed numerically, set standards of what has been and can be achieved, for instance, socio-economic concepts such as production, employment and income are comprehensible only in relative terms.

However, Frumkin (1994) considers economic indicators as more than statistics. They are the factual base for public policies and actions that affect the economic well-being of the nation as a whole. He explained that as the economy continually operates in recurring phases of rising and falling activity in the business cycle, economic indicators are, therefore, used to measure the overall economic activity for classifying it as rising (expansion) or falling (recession), as well as to determine the cyclical turning points of these expansions and recessions.

Essentially, economic indicators have been developed to serve as tools for business conditions analysis and forecasting. One of the major contributions to the work of business cycles is the statistical indicators analysis. The origin of the statistical indicator traces mainly to the pioneering works of the National Bureau of Economic Research (NBER) in the United States during the 1930's. The NBER was requested to devise a system that would signal when an economic depression was ending. The NBER economists, under the leadership of Wesley Mitchell and Arthur F. Burns, developed the basic idea of reference cycles in 1938. On examining 487 statistical series, they chose 71 time series as statistical indices of cyclical
revivals. The idea was developed even further by Moore (1961). In his study, 801 monthly and quarterly time series were analysed for the United States which had been prepared by the NBER. Of these, 225 series were chosen as economic indicators on the basis of their conformity with the reference business cycle. This number was finally reduced to 21. Moore (1980) emphasized that not only can these time series serve as indicators of past and current economic activities, they can also be used for predictive purposes.

Hence, economic indicators serve the general purpose of:

1) obtaining a better understanding of how an economy is performing;
2) making a realistic judgement of the government's economic policies;
3) facilitating comparison of the economic well-being of different countries; and
4) making forecasts of future performance of the whole economy or individual sector of the economy.

More specifically, economic indicators are also developed to enable the prediction of certain economic events happening. Many economists have investigated the causes of peaking in a business cycle. Eckstein and Sinai (1986) categorised events that precede recessions as arising out of the following events:

1) Boom periods, when demand has risen above the long-term trend, causing capacity constraints;
2) Demand shocks, which are caused by a sudden falling demand;
3) Supply shocks, which are caused by curtailment of supplies or other disruptions such as labour strikes;
4) Price shocks, which are created by movements outside normal supply and demand relationships such as price controls; and
5) Credit restrictions, where financial distress is reflected in lessened availability of money and credit.

These events need to be predicted well in advance so that actions can be taken to avoid, or at least, lessen the effects of a forthcoming recession.
4.4 Basic methods of interpretation

Based on the definitions given in Section 4.2, indicators can be inferred as measures that are obtained by means of further processing statistics so as to fit a framework of economic or social concerns. In essence, indicators are manipulated or processed statistics designed to express structure or change of phenomena related to economic or social interests. Therefore, in order to reveal and fully understand their acquired meaning or latent information, several basic methods of interpretation have been developed. The following are some of the methods commonly used for interpreting economic indicators.

a) Nominal and real terms

When interpreting economic figures, it is important to distinguish between the effects of inflation and changes in the real level of economic activity. For instance, a volume output indicator provides information about the changes in volume, and not price. It is also known as output in constant prices, real prices or real terms. On the other hand, a value output indicator reflects changes in both volume and price. An output measured in actual selling price is known as output in current price, nominal price or nominal terms. In short, values or outputs in current prices, nominal prices or nominal terms include the effects of inflation; while volumes or outputs in constant prices, real prices or real terms exclude any inflationary influences. Generally, price indicators are produced and used to convert output in current prices to constant prices. They are also known as price deflators.

b) Index numbers

Often, indicators are developed using index numbers. Frumkin (1994) considers index numbers as a convenient way of quickly assessing the direction and level of changes in economic activity. Essentially, an index number is a relative measure which expresses the relationship between two figures, that is, the current and the base. The base figure is set at 100 and subsequent figures are obtained with reference to it. Thus, an index number shows percentage change over time or difference at a point in time. It may be either simple or composite. A composite index combines two or more indices to form a new single index. The most common method of constructing a composite index is to calculate a weighted average of the indices used.

The main types of indicators that use index numbers are:
- price index, which deals with changes in price only and is generally used for deflating purposes;
- volume index, which measures changes in volume, such as the Index of Industrial Production; and
- value index, which reflects changes in both volume and price, such as the Index of GDP.

c) Net and percentage changes

Net and percentage changes are two commonly used methods for interpreting economic indicators. A net change is an absolute measure which reflects the amount difference between two periods. On the other hand, a percentage change uses percentages as a consistent yardstick for interpreting changes, and thus is a relative measure. In identifying critical periods over a period of time, change measures are more effective than those which show only total amounts. These periods will be more apparent since the figures would indicate the magnitudes of the change. Although both net and percentage change reflect change over time, there is a main difference in their usage. For example, an interest rate increases from 10 per cent to 13 per cent, the net change is 3 percentage points, but the percentage change is 30 per cent.

d) Growth rates

Growth rates are most commonly used for interpreting time series of economic indicators. Some of the measures of growth rates are:

*12-month or 4-quarter change:*
This measure compares the figure of a particular month or quarter with that of the same month or quarter in the previous year. For example, orders rose by 2.6 per cent between the third quarters of 1989 and 1990.

*Annual change:*
This measure compares the total or average figure for one calendar or fiscal year with that in the previous year. For example, orders in 1990 were 2.7 per cent higher than in 1989.

*Change to year-end:*
This measure compares year-end with year-end. For example, orders fell by 2.1 per cent over the
four quarters to end 1990.

**Long-term change:**
This is also the long-term growth rate which is obtained by averaging annual rates. However, it is only appropriate if the changes are fairly uniform.

e) Moving averages

When the time series of an indicator shows erratic fluctuations, it is common to apply moving averages to smooth out the irregularities so as to reveal the underlying trend. In essence, the application of this method is most appropriate when interpreting indicators with volatile figures. The moving average can average any number of periods, although the more periods it covers, the slower it will be to show any changes in trend.

f) Seasonality

Most economic figures show a seasonal pattern that repeats itself every year. By eliminating seasonal effects, the figures can be more easily compared and examined for trends, cycles and irregular components. When interpreting indicators containing seasonality, seasonal adjustment has to be carried out to adjust raw data for the observed seasonal pattern. For instance, if output in a particular month is typically higher by 50 per cent than the monthly average, the seasonal adjustment would involve dividing all figures for that month by 50 per cent. Many published figures are seasonally adjusted to aid interpretation of economic indicators.

4.5 Economic indicators

4.5.1 National output and growth

National output reflects the state and composition of a country's overall economy and is typically summarised in measures of GDP which are broad indicators of the total value of goods and services produced and purchased in the private, public, domestic and international sectors of the economy (Vaitilingam, 1994). Indicators of national output have long been the most popular and comprehensive in terms of measuring a country's development (Horn, 1993). The following are
some of the common indicators of national output and growth.

4.5.1.1 Nominal and real GDP

Nominal GDP is an indicator of total economic activity in current prices. The significance of this indicator is that it describes the total level of production in a country and is often used as a yardstick for measuring economic development. This indicator is presented as quarterly and annual totals.

A real GDP indicator measures total economic activity in constant prices. It is most useful for tracking economic developments of a country over time. Real GDP figures reveal changes in economic output after adjusting for inflation and thus, indicates a country's GDP growth. It is presented as quarterly and annual totals, but often interpreted using annual percentage changes.

4.5.1.2 GDP per head

This is an indicator of output per person, that is, GDP divided by population size. Its significance is that it provides a good guide to a country's general living standards since it is often used as an indicator of overall economic welfare. Therefore, when real GDP per head increases, it indicates an improvement in the overall economic well-being of a country. It is presented as quarterly and annual totals, while interpreted using nominal totals and changes in real terms.

4.5.1.3 Productivity

Productivity is essentially an indicator of efficiency and potential total economic output. It represents the nation's efficiency in producing goods and services by measuring the output per unit of factor inputs, that is, land, labour and capital. However, land is basically fixed and capital is very difficult to measure and so labour productivity tends to be the focus. Incidentally, labour productivity can also reflect capital investment. for instance, a company using more machinery will probably produce more output per person than one that uses less. Hence, labour productivity also offers a guide to capital productivity. Other factors which affect labour productivity include social attitude, work ethics, unionisation and training. However, these are not measured directly by economic statistics.
Productivity is important because greater efficiency increases the quantity of goods and services available for private and public needs. The relationship of productivity to inflation, average weekly earnings and employment is also important. When productivity increases rapidly, more goods and services are available at lower prices because of lower production costs. Therefore, high productivity growth permits higher wages without increasing production costs and inflation. Productivity is highly cyclical since employment and capital are less flexible than demand and output (The Economist, 1994). Productivity figures are generally presented as index numbers, although they can also be calculated in money terms. In terms of index numbers, interpretation is based on trend, especially relative to other countries.

4.5.1.4 Cyclical or leading indicators

These indicators essentially measure the economic cycle. They are useful tools for short-term predictions of economic activity. They are developed on the basis that cyclical patterns exist in economic series and indicators which turn in advance of the general economic cycle, or GDP, can be used to predict future economic developments. It is common to combine several leading economic indicators into a composite one. Generally, trends are removed, irregular fluctuations are smoothed, and the series are combined into weighted averages in index form. Leading indicators are known to turn six to twelve months ahead of GDP and so the composite index can serve as a guide to the general cycle. Most composite leading indicators are used only to identify turning points of a cycle, although percentage changes can also be applied to broadly suggest the magnitude of fluctuations in the overall level of economic activity.

4.5.2 Population and employment

Measures of population and employment are vital indicators of long-term economic growth in a country. The size and age structure of the population provides an indication of long-term pressures on the economy. GDP or total output must grow at least at the same pace as the size of population if output per head is not to decline, while an increasing number of people of working age may signal either enhanced productive potential or more unemployment. In the short term, unemployment is also an excellent indicator of the state of the economic cycle. High unemployment reflects a recessionary gap, while low unemployment is broadly indicative of inflationary pressures, especially when the cycle is peaking. In general, employment data are essential guides to personal incomes, wages and unit labour costs. These are the basic
components for measuring GDP on an income basis and are also useful in assessing inflationary pressures. The following are the main indicators of population and employment.

4.5.2.1 Population

Population is a measure of the total number of people in a country. Since real GDP must grow at least as fast as the size of population if living standards are not to fall, the significance of this indicator is that it serves as a yardstick for minimum GDP growth. It is presented as annual total numbers and when interpreting this indicator, the focus is on the age structure and annual percentage changes.

4.5.2.2 Labour or workforce

Labourforce is a measure of the number of people that are employed, self-employed and unemployed but are ready and able to work. The total number is sometimes known as the economically active population. In essence, it is an indicator of maximum potential output in a country. The size of workforce are generally affected by three factors: size and age structure of population; migration; and the proportion of population participating in economic activity. It is presented in total numbers and the focus of interpretation is also on the structure and percentage changes.

4.5.2.3 Employment or payrolls and hours worked

Employment represents workers engaged in gainful work. It is a measure of total employment in a country, that is, the total number of employed and self-employed people. It is an indicator of current output potential since the level of production in a country depends on the number of people employed, hours worked, education and training. Employment is also the main source of household incomes, which, in turn, are spent on consumer goods and services. Since consumer spending accounts for almost 65 per cent of the GDP, employment is a key factor affecting economic growth. The main sources of data are censuses and surveys of population and employment. By nature, employment is highly cyclical. When demand increases, companies tend to increase overtime first. They only take on more employees when higher demand is perceived to be strong and durable. When demand turns down, working hours are cut before jobs. Therefore, hours worked and overtime are early signals, while employment is a
confirmation of thriving demand. The employment indicator is presented as totals but the focus of interpretation is on percentage changes.

4.5.2.4 Unemployment

Unemployment is a measure of the total number of people out of work but are ready and able to work. It indicates spare labour capacity which is regarded as wasted resources of a country. When presented as a rate, unemployment is measure as a percentage of the total workforce. Unemployment rate reflects the slack or tightness in labour markets and is a major indicator of the degree to which the economy provides jobs for those seeking work. It is also used to analyse trade-offs between unemployment and inflation. The main sources of data are labour force sample surveys and returns from employment agencies of the numbers registered for employment. The former is adopted in the United States and Japan for compiling unemployment rates, while the latter is used in the UK and France for obtaining total numbers (Moore and Moore, 1985). There is a clear cyclical pattern in unemployment. As demand increases, companies employ more workers and unemployment decreases. The reverse is true when demand falls. In the long term, the structure of unemployment helps in identifying economic problem areas. The indicator is presented as total numbers or percentages. When interpreting these figures, the focus is on the structure and percentage changes.

4.5.3 Fiscal indicators

Fiscal indicators are concerned with government revenue and expenditure, which are significant influences on the circular flow of incomes. Taxes and duties are leakages, while spending is an injection to the circular flow. In essence, fiscal activities allow governments to provide public services, redistribute incomes and influence the overall level of economic activity. They are one of the government's tools for controlling the economy. The following are some of the main indicators of a country's fiscal policy.

4.5.3.1 Public expenditure

This is an important indicator of fiscal policy which measures spending by the government. It is of great significance because it affects aggregate demand and size of the budget deficit. Government spending provides public services including law and order, defence, education and
health, public utilities, and infrastructures like roads and bridges. Such spending is an injection to the circular flow of income and has a considerable effect on aggregate demand. Public spending may be classified into two main types: current spending; and capital spending. The first type comprises public sector employees' salaries, public housing subsidies, social security or welfare benefits, and interests on national debt. Capital spending is mainly fixed investment in infrastructure and dwellings. Generally, spending tends to rise above target or budget projection if the economy grows more slowly than expected; indicating that the government is overspending (The Economist, 1994). It is presented as monthly and annual totals in current prices. The focus of interpretation is on totals and trends.

4.5.3.2 Government revenues

This is a measure of government receipts mainly from taxes and duties. Its significance includes affecting aggregate demand and being a major source of finance for government spending. Generally, taxes have a major effect on economic activity and most importantly, they have an automatic stabilising influence. They normally increase at the peak of the economic cycle which helps to moderate consumer demand when more people are earning and spending more. During a recession, taxes decline to help offset falling incomes. There are two main categories of taxes: direct; and indirect. The first category include taxes on personal and corporate incomes, capital gains, capital transfers, and inheritances and wealth. Indirect taxes are those that are levied on goods and services such as value-added tax, customs and excise duties. Similarly, it is presented as monthly and annual totals in current prices and the interpretation is based on totals and trends.

4.5.3.3 National debt; government or public debt

This is a measure of long-run cumulative total of government spending less revenues. Since a country's public or national debt is financed mainly by its citizens, it may be seen as a transfer between generations. Besides reflecting inter-generational transfer, Frumkin (1994) highlighted that government debt also affects interest rates through sales of new securities and refinancing of existing debt in bond markets. A large debt provides substantial low-risk investment outlets as an alternative avenue for investing funds. During periods of considerable economic uncertainty, investment funds may be channelled towards government securities, resulting in higher interest rates for household and business borrowers. Generally, it can be expected that when public debt is high, there will be a reduction in government spending or an increase in taxes or even both. It
is presented as annual totals in current prices. When interpreting the figures, the focus is on the totals, particularly as a percentage of GDP, and trends.

4.5.4 Consumers

Consumers play a vital role in a nation's economy since personal consumption accounts for between half and two-thirds of GDP. In general, if consumers' incomes are boosted, their level of spending on goods and services also increases. These spendings become income for others, who in turn spend their incomes on goods and services. The process is repeated and the multiplier effect is generated which brings about increased levels of production in the whole economy. The following are two main indicators relating to consumers.

4.5.4.1 Personal income, disposable income

Personal income is the current income received by the personal or consumer sector from all sources. It comprises wages and salaries, rents, interest and dividends, and current transfers such as social security benefits. Personal disposable income is personal income after the deduction of personal direct taxes. As personal income represents the main component of consumer purchasing power, it has a prime influence on consumer spending. In essence, indicators of personal incomes form the basis for consumption and savings, and a direct relationship may be implied between them. As incomes are affected by the economic cycle, it is generally advisable to look for sustainable growth in real incomes as too rapid increases may be inflationary. It is presented as money totals, and growth rates are the main focus of interpretation.

4.5.4.2 Consumer and personal expenditure, private consumption

This is a measure of spending by private individuals or households on goods and services. It derives its significance from being a key component of GDP. Generally speaking, a 1 per cent rise in consumer expenditure contributes to about a 0.6 per cent increase in total GDP (The Economist, 1994). Given its proportion of contribution, consumption is clearly a critical target of government macroeconomic policy. Vaitilingam (1994) highlighted that in terms of the state of the overall economy, growth in personal consumption often leads a general recovery from recession, encouraging manufacturers to invest. However, he also recognises the problem with consumer spending booms and that is, the trade deficit often begins to grow and inflation
escalates. This occurs when consumption grows faster than productive capacity, resulting in rising levels of imports. This can have adverse implications for both the balance of payments and for domestic inflation where prices of imported goods drive up the general price level. This would require the government to act counter-cyclically, perhaps raising personal taxes so as to reduce personal disposable incomes. The retail sector is particularly affected by consumer spending patterns, benefitting considerably from a recovery. It is also presented as money totals with growth rates being the main focus of interpretation.

4.5.5 Investment and savings

Investment is the addition to the nation's stock of tangible capital goods. It lays the basis for all future production, income and consumption. Savings, on the other hand, provide the finance for investment. Together, they are the key determinants of the long-term performance or growth of an economy. Owing to the durability of capital goods, investment decisions depend on three elements: (1) the demand for the output produced by the new investment; (2) the interest rates and taxes that influence the costs of investment; and (3) the state of expectations and business confidence. The following are two main indicators of investment and savings.

4.5.5.1 Fixed investment and GDFCF

Fixed investment is spending on physical assets which include: infrastructure such as roads and bridges; buildings such as dwellings, factories and offices; plant and machinery; and equipment such as computers. Investment in these assets contributes directly to GDP and generally provides the potential for higher output in the future. Fixed investment accounts for an average of about 20 per cent of GDP in industrialised economies, that is, a 1 per cent rise in fixed investment contributes about 0.2 per cent to GDP in the same period (The Economist, 1994). Investment is highly cyclical. In the private sector, firms are more likely to invest during favourable economic conditions but tend to cut back on fixed investment when conditions are reversed. Government investment spending is another major source of national fixed investment. It is often used for counter-cyclical purposes and tends to increase during economic downturns so as to provide a boost for the economy. There are several advance signals for fixed investment such as investment intentions, construction spending, housing starts, car sales, manufacturing production levels and imports of capital goods. It is presented as values, volumes and index numbers. The main focus of interpretation is on volume trends.
4.5.5.2 National savings, savings ratio

National savings measure total savings in an economy, that is, the sum of savings by the private sector and the government. Private savings are the sum of savings by individuals and companies. Government savings are general government revenue less current expenditure. Both private and government savings are highly cyclical. Businesses need to hold liquid reserves to cushion themselves against the economic cycle and to provide funds for expansion, while governments' saving policy is largely influenced by political decisions. Savings, or deferred consumption, has a major influence on investment and interest rates. As mentioned earlier, savings are the main source of finance for investment. When national savings levels are high, the availability of funds for borrowing is reflected by lower interest rates, leading to more investment and spending. Hence, domestic savings are an important indicator to monitor. It is presented as totals for national savings and percentages of GDP for savings ratio. Trends are the main focus for interpreting these indicators.

4.5.6 Industry and commerce

In addition to information on national output, there is a wide variety of important economic indicators relating to industry and commerce. All of these indicators are valuable guides to the past, present and future movements of both the output and expenditure measures of GDP and hence, the overall state of the economy. In essence, national accounts provide a broad historic picture of the state of an economy, while the output data break it down by market and industrial sector. The following are the main indicators of industrial and commercial output and expenditure.

4.5.6.1 Business conditions

This indicator provides anecdotal evidence of business climate and is valuable as early warning of changes in economic cycle. Monthly or quarterly surveys are conducted to obtain industrial companies' general perception and expectations relating to business conditions, usually in manufacturing. Responses are subjective but they give early signals of changes in economic trends. The indicator can be presented as an index number or a percentage balance of optimistic and pessimistic companies. For instance, in the former case, a composite index above 50 indicates an expanding manufacturing sector, while a figure below 50 indicates a contracting
sector. In any case, the main focus of interpretation is on trends.

4.5.6.2 Industrial and manufacturing production

The output of production industries is the total of value-added output of manufacturing companies, mines, energy (oil and gas) and water supply industries. In this case, value-added is the basis of measurement, that is, the value of output less the cost of raw materials and other inputs, since the main concern is to indicate the net contribution of production industries to GDP. It is common to distinguish manufacturing production from total output or industrial production to obtain the value-added output of manufacturing companies only. Hence, two series are released together. On the average, the difference between manufacturing and industrial production is about 10 per cent (The Economist, 1994). This gap is more significant where the energy producing sector is large. Generally, indicators of production industries output are strongly indicative of the state of the business cycle. This is because the output of industries that produce capital goods and consumer durables is significantly reduced and increased in a recession and recovery, respectively. They are presented as index numbers in volume terms and the focus of interpretation is on trends in volume terms.

4.5.6.3 Manufacturing orders

This is an indicator of new orders received by manufacturing companies. It is indicative of output in the short term and generally, there is a knock-on effect from such orders. For instance, an order for refrigerators would prompt an order for metal pressing, which in turn would invoke an order for sheet steel. Buoyant order books indicate upward pressure on employment and output over the next few months. Although this is a good sign, it may also suggest a rise in inflation if the economy is already operating at close to full capacity. High order backlogs or low inventories may also be worrying signs; bottlenecks in one industry create shortages of inputs in others. Strong orders also tend to increase imports of materials and intermediate goods, but this may be offset by exports. Orders also provide an early signal of changes in the economic cycle. A rise in orders may indicate the end of a recession, and a fall may indicate that the cycle is peaking. Normally, total orders are distinguished between domestic and export. Domestic orders by sector are indicative of the structure of local demand. Larger orders for capital goods suggest more investment activity and more output in the future. Orders from overseas reflect export competitiveness and the economic cycle in overseas markets. Surveys are conducted among
manufacturing companies and the information obtained on new orders by sector is presented as money totals or index numbers. Interpretation of these figures is based on the structure and trends.

4.5.6.4 Construction orders and output

The measures of construction orders and output are concerned with activity in the construction sector. They are generally indicative of new investments and future output. There are several main series including: orders; permit issued; the value of work put in place; and value-added in nominal and real terms. Construction orders signal future demand for building materials and labour. They also produce knock-on effects for other sectors of the economy such as the service and manufacturing industries. Value-added in construction indicates the net contribution of construction to GDP, and hence reflects the significance of construction in the whole economy. Since construction work is fixed investment, it contributes to GDP and lays the basis for future economic growth. New factory and office buildings provide a direct foundation for higher economic output. New infrastructure improves social welfare and generally boosts productivity. Construction orders and output indicators are presented as values of orders or volumes of construction, but their interpretation focuses on trends in volume terms.

4.5.6.5 Housing starts, completions and sales

These are three different measures of housing construction. The three main series indicate: the number of residential dwellings that have commenced construction; the number of residential dwellings that have completed construction; and the number of residential dwellings sold. For each series, the figures are distinguished between private and public dwellings.

A housing start takes place when foundation work has begun. It reflects the level of demand for construction, and hence, demand for construction materials and labour over the next few months. It also implies a housing completion at the end of the construction period. New housing construction is important to the overall economy. Construction results in the hiring of workers, the production of construction materials and equipment, and the sale of large household appliances and furniture. The rate of new housing construction is heavily influenced by the growth of the number of households in the long run, and by the growth of real family income and the level of mortgage interest rates over shorter periods. As houses are very durable and there is
little need to replace them frequently, the purchase of new housing is usually deferred until incomes and interest rates make it affordable. Typically, housing starts increase when interest rates are low or incomes in general are rising, and they fall when interest rates are high or incomes are growing slowly or declining. Hence, housing starts fluctuate considerably during business cycles.

A housing completion is indicative of a house sale, a new mortgage advance and increased consumer demand for furnishings and fittings. Housing sales are linked to the level of completions, but the main focus is on turnover of existing dwellings. Housing turnover is usually stimulated by surging house prices, rising incomes relative to house prices and lower mortgage rates which encourage borrowing. In general, residential construction is a good leading indicator of economic activity (The Economist, 1994). Housing starts have been classified as a leading indicator of business activity (Frumkin, 1994). As interest rates rise, housing starts will fall, signalling a downturn: a revival of house-building usually means economic recovery is forthcoming. The indicators are presented as number of units per month and their interpretation is based on trends.

4.5.6.6 Wholesale sales or turnover, orders and stocks

This indicator measures sales by wholesalers and is mainly indicative of general demand. A fall in wholesale sales or a rise in wholesale inventories usually suggests or confirms slack in business and retail demand. Wholesale sales are also an important link in the supply chain. Wholesalers channel imports and domestically produced or processed goods through to final users. Where stocks and orders are available, they provide a useful check on economic trends. Most importantly, the volume of sales for durable goods is an early indicator of demand pressures. It is presented as monthly index numbers, and the rate of change in the volume of sales is the main focus of interpretation.

4.5.6.7 Retail sales or turnover, orders and stocks

This indicator measures sales by retailers and represents the dollar receipts of retail establishments for goods and services sold to households, businesses and governments. The sales figures provide an important and timely indicator of spending at retail outlets and is mainly indicative of consumer confidence and demand. Seasonality is present in such data and published
series are usually seasonally adjusted. Retail sales are also subject to cyclical variations. In times of financial stress, consumers would cut back on non-essential spending, which result in a decline or less rapid growth in retail sales. Usually, spending on durables will be the first to decline. A downturn in retail sales would lead to lower wholesale sales, slacker factory orders, an accumulation of stocks and, eventually, a cutback in production. Where figures for retail stocks and orders are also available, they provide useful advance warning. Retail sales are nearly coincident with GDP and, therefore, provide an early indication of economic trends. It is presented as monthly index numbers and its interpretation is based on the rate of change in the volume of sales.

4.5.7 Trade and exchange rates

A national economy's interaction with the rest of the world can be tracked through two basic groups of economic indicators: the balance of payments, which is an accounting record of international trade and financial flows between countries; and the exchange rates, which are values of the local currency in terms of other currencies. The following are the main indicators of these two groups.

4.5.7.1 Imports of goods and services

This indicator measures a country's purchases from abroad. Generally, a country imports goods and services because it cannot produce them domestically or there is comparative advantage in buying them from abroad. Although imports add to economic and social well-being, high volumes may displace domestic production and drain financial resources. Imports of goods and services as a percentage of GDP indicates the degree of dependence on imports; the higher the figure the more imports displace domestic output and the more vulnerable is the economy to changes in import prices. However, a high volume of imports of intermediate and capital goods is generally good as these are used in turn to manufacture other goods or to generate invisible earnings by providing services. This adds value to GDP and may even contribute to future export growth. Increases in the volume of imports of consumer goods are a direct signal of consumer demand. They imply that domestic producers cannot meet the required price, quality or quantity. Import volumes tend to move cyclically. In general, they increase when domestic demand is buoyant, and therefore. imports are often regarded as a safety valve which offsets the inflationary pressures that arise when domestic firms are operating at close to full capacity.
Imports are also linked to exports. An increase in exports boosts GDP, which in turn induces demand for domestic and imported goods to rise as well. Seasonal adjustments are also necessary for these trade figures. This indicator is presented as money values or volumes and index numbers. Besides quantity, value figures also reflect changes in foreign prices and exchange rates. The focus of interpretation is on the growth rates of imports as a percentage of GDP.

4.5.7.2 Exports of goods and services

This measure is indicative of sales of goods and services to other countries. In essence, exports generate foreign currency and economic growth. Export growth boosts GDP which in turn implies more imports. However, when a country is highly dependent on export trade, it also means increased vulnerability to the economic cycles of the importing countries. Demand for exports largely depends on economic conditions in foreign countries, price factors such as relative inflation and exchange rates, and product quality and reliability. It is also subject to seasonal and cyclical influences. Export volume indicates changes in real terms, while value gives the overall balance of payments position. Export indicators are presented as money values or volumes and index numbers. Interpretation is also based on the growth rates of exports as a percentage of GDP.

4.5.7.3 Trade balance, merchandise trade balance

This is a measure of the net balance between exports and imports of goods and services. It is indicative of a country's fundamental trading position. Generally, trade balance impacts the GDP, employment, inflation and the exchange rate. A surplus in the trade balance or a reduction in the trade deficit stimulates economic growth and job expansion, while a deficit or reduction in the surplus restrains economic growth and employment. A large trade deficit may signal supply constraints, especially if it is accompanied by high inflation. This suggests that domestic firms are unable to boost output to match higher domestic demand, and hence the volume of imports increases. The deficit may act as a safety valve and divert potentially inflationary pressures. Alternatively, an increasing trade deficit may signal a loss of export competitiveness by domestic firms in overseas markets. In addition, the balance of trade in goods and services also measures the relationship between national savings and investment. A deficit indicates that investment exceeds savings and that absorption of real resources exceeds output. This indicator is presented
as money values and the focus of interpretation is on total balances.

4.5.7.4 Nominal exchange rates

This is a measure of the price of one currency in terms of another. Exchange rates affect the economy in several avenues such as influencing external trade, capital flows and other international payments. They determine the competitive position of domestic goods in export markets, and also affect inflation and monetary policies domestically. All economic policies affect exchange rates, although changes in interest rates have the most direct and visible influence. The exchange rate is hence the broadest indicator of monetary policy. A lower currency tends to boost production and inflation domestically while a higher currency tends to lower production and inflation. The most immediate effect of a weaker currency is higher domestic inflation due to more expensive imports. Although exports priced in foreign currencies and inflows of rents, interest, profits and dividends generate more income in domestic-currency terms, the trade and current-account balances generally deteriorate. However, over a period of time when relative price movements cause a shift from imports to domestic production and exports, the GDP is boosted and trade and current-account balances usually improve. It is presented as units of one currency for one unit of another. Interpretation is based on trends.

4.5.8 Money and finance

Money is a measure of value, a medium of exchange and a store of wealth. It is also a bridge between real and nominal magnitudes. Financial markets bring together the supply of savings and the demand for money to finance businesses and consumer spending. The availability of finance allows the completion of commercial transactions and the spreading of risks. In essence, money and finance are two intertwined elements: finance and the markets that determine the price of capital; and money, the force that lubricates the whole economic system, connecting real and nominal values. The following are the major indicators of money and finance.

4.5.8.1 Money supply, money stock, M1...M3, liquidity

This is a measure of notes, coins and various bank deposits. It represents the value of certain financial assets held by households, businesses, non-profit organisations and governments. It is also indicative of the level of transactions and, perhaps, inflation or output. Money is currency in
circulation plus bank deposits and, therefore, money supply reflects assets that are very liquid, and consequently, are readily available for future spending.

The total amount of money in circulation, the money stock or money supply, is often called M. There are several alternative definitions of money supply measures, which range in coverage of financial assets from M1 as the most limited to M3 as the broadest. For example, M1 or narrow money includes non-bank private sector's holdings of notes, coins and demand deposits, while M3 or broadest money includes all of these plus savings deposits, time deposits and money-market deposits. Among the various classifications of money supply, M2 is the most popular. It comprises M1, time and savings deposits. In terms of liquidity, M1 is the most liquid, while M2 and M3 are increasingly less liquid.

In economic theory, the amount of money is related to spending and the resultant economic growth, employment and inflation. A larger money supply means more spending, higher economic growth, employment and inflation. Besides, money supply also reflects the decisions of households, businesses, and governments to hold their assets in certain financial forms such as currency, savings account, money market deposit accounts and others. Generally, money supply is of policy interest because it influences interest rates which are the price of money. The level of interest rates affects the quantity of loans and in turn has an impact on the level of national output, employment and consumption. Therefore, it is common for governments to use money supply to regulate interest rates so as to control the level of economic activities. They affect the supply of money by expanding or restraining the amount of commercial bank reserves available for loans, which in turn affects interest rates. This indicator is presented as money totals and the focus of interpretation is on percentage changes over time.

4.5.8.2 Bank lending, advances, credit, consumer credit

This measures the amount of loans made to private individuals, companies and the public sector. It is a general indicator of monetary conditions in a country. Changes in overall bank lending figures indicate the effectiveness of monetary policy, while changes in lending to different sectors may indicate trends in different parts of the economy. There are two main categories of borrowing: personal and consumer borrowing; and corporate borrowing. The first category involves borrowing by households to finance the purchase of homes and consumer goods and services. Such borrowings tend to be sensitive to interest rates and consumer confidence.
Growth in household credit can be inflationary when demand is already buoyant. In the second
category, companies borrow to finance their operations, investment and takeovers. Corporate
borrowing for business operation generally slackens when the economy is booming since funds
are generated by buoyant sales. However, borrowing for investment activity may increase as
companies are most optimistic during the boom. A breakdown by industry will reveal trends in
various sectors. High borrowing may reflect either optimism and investment or recession and
debts. Output, orders and capacity utilisation figures will indicate which is the case. This
indicator is presented as monthly totals and the focus of interpretation is on trends.

4.5.8.3 Interest rates, short-term and money-market rates

Interest represents the cost of borrowing money. Hence, interest rates are the price of money. It
is a general indication of monetary conditions, expectations and creditworthiness. An interest
rate, or yield, is the annualized percentage that interest is of the principal of the loan. The level
of interest rates for different loans reflects the length and risk of the loan.

Interest rates tend to rise and fall in line with the level of economic activity. Whether by
government action or by constraints of supply and demand, interest rates tend to rise when
economic activity is buoyant and fall when it is slack. Interest rates have a significant impact on
borrowing and spending. Lower interest rates encourage borrowing, which leads to more
consumer spending and investment, increased imports, a higher level of economic activity and
possibly faster inflation. Higher interest rates do the reverse. Interest rates also have an
influence on exchange rates and foreign trade. Changes in interest rates affect the relative
attractiveness of holding a currency. An increase in interest rates of a country will cause a higher
demand for its currency, resulting in an appreciation of its value. Imports become cheaper but
exports are dearer, hence the trade balance may be disrupted. Other countries which want to
maintain exchange-rate relationships or prevent money-market outflows may be forced to raise
their interest rates as well. This indicator is presented as annual percentage rates and the focus of
interpretation is on trends.

4.5.8.4 Stock and share prices

This is a measure of prices of company share capital. On the whole, it reflects economic
expectations and is, therefore, useful as a leading indicator of the economic cycle. Share prices
are the discounted value of future dividend payments including a premium for risks. Future dividends depend on company profits, which in turn reflect the quality of management and the state of the economy. Share prices are highly cyclical. When investors expect a recession, they are less keen to buy equities and their prices fall. As soon as an economic recovery is apparent, investors switch into equities, causing prices to increase. Stock prices also influence the course of future economic activity because they affect retail sales, home sales, and plant and equipment expenditures. High or rising stock prices encourage consumer and investment spending because they promote optimism about the economy. Stock prices also affect consumer spending because of the effect of stocks on personal wealth. They influence investment spending because high stock prices make it easier for businesses to finance new investment by selling new equity stock or by obtaining loans through new bond sales or other debt financing. The indicators are presented as individual prices in monetary terms and index numbers of average prices. The focus of interpretation is mainly on broad market indices.

4.5.9 Prices

Price indicators measure levels and changes in the prices of particular sets of goods. Hence, they are direct measures of inflation. There are three main adverse effects of inflation. First, it obscures relative price signals since it is difficult to distinguish between changes in relative prices and changes in the general price level. This distorts the behaviour of individuals and firms, and so reduces economic efficiency. Second, since inflation is unpredictable, it creates uncertainty, which discourages investment. Third, inflation redistributes income such as, from creditors to borrowers. However, despite these effects, economists still believe that marginal inflation is a natural and unavoidable condition of a healthy, growing economy. Thus, it is essential that the rate of inflation is monitored and controlled constantly so as to keep it within the acceptable level. The following are the main price indicators of several essential commodities.

4.5.9.1 Export and import price index

This index measures price changes in traded goods due to changes in the value of the currency and changes in the markets for the goods. It helps to identify cost pressures, potential exchange-rate problems and changes in export competitiveness. Import or export price indices, including the GDP deflators, capture changes in both the prices and the composition of a country's external
Export price indices are usually compared with domestic price indicators, such as the producer price index for domestic produced goods, to determine whether local manufacturers are passing on cost pressures to foreign buyers; or perhaps being constrained from doing so owing to international competitive pressures. On the other hand, import price indices are used to judge external cost pressures. Import prices that are rising faster than domestic prices are a clear sign of imported inflation. These indicators are presented as index numbers and their interpretation is based on percentage changes.

4.5.9.2 Property price index

This is an indicator of the general price level of private real estate properties. It reflects changes in the price level of properties caused by the forces of demand and supply, and general economic conditions. Generally, it affects property developers' expectations of the future, as well as, potential investors' confidence. It also has direct effects on the level of demand for construction. It is subject to cyclical variations because during a recession, the demand for fixed investments, such as properties, is low and prices will generally fall. When economic conditions are good, individuals and firms are more willing to invest in properties, hence pushing demand and prices up. Hence, the index is also indicative of the state of the economic cycle. It is presented as index numbers and interpretation is based on percentage changes.

4.5.9.3 Building material price index

This is a measure of movements in the purchase price of building materials used in construction. It reflects cost pressures in the building materials manufacturing sector and has a direct impact on total construction costs. Essentially, increased demand over a stagnant supply of materials will translate into higher costs. The prices of building materials fluctuate in response to changes in demand for construction, which in turn is influenced by general economic conditions. Recession brings lower demand for construction and hence prices for building materials are weaker. Price data are obtained from producers and importers of building materials and the main groups of materials included in the index vary from country to country. It is presented in index form and the focus of interpretation is on percentage changes.
4.5.9.4 Consumer or retail price index

This index gauges the overall rate of price change for a fixed basket of goods and services bought by households over time. Essentially, it indicates the rate of inflation experienced by a typical household. The consumer price index is one of the most popular, or widely quoted, indicators of inflation. It is also known as the retail price index or the cost of living index. The basket's composition and weighting are usually based on surveys of household or family expenditure habits and hence, vary from country to country. In the formulation of fiscal and monetary policies, trends in this index are a major guide in determining whether economic growth should be stimulated or restrained (Frumkin, 1994). It is presented as monthly index numbers and its interpretation is based on percentage changes.

4.5.9.5 GDP deflators

These are indicators of overall national price changes. They are the broadest and best indicators of economy-wide inflation. They enable comprehensive analyses of the sources of inflation in the consumer, investment, government, and international components integrated in a statistically consistent framework. Essentially, they measure the difference between current and constant price GDP and its components. They are valuable for identifying trends and obtaining advance warning of price changes in many areas. Since the deflators cover many items and price movements among them average out, they do not fluctuate as much as narrower indices such as those covering only consumer prices. They are presented as quarterly and annual index numbers and interpretation is based on percentage changes.

4.5.9.6 Unit labour costs

This is a measure of labour costs per unit of output. It is an indicator of cost pressures and competitiveness. At the national level, it is the average cost of producing one unit of output, that is, labour costs divided by GDP. In a narrower context, it represents the relationship of labour costs per hour and productivity. It is often regarded as a key indicator of the cost efficiency of labour. If unit labour costs fall, the same output can be produced with less expenditure on labour. Therefore, it essentially reflects two factors, labour costs and productivity. Relative movements in unit labour costs are important signals of international competitiveness in traded goods. A country with unit labour costs rising faster than those of its competitors may
temporarily absorb pressures by cutting profit margins or improving efficiency. However, in the longer term, deteriorating competitiveness will reduce exports, output and also employment. Unit labour costs generally lag behind the economic cycle by 12 to 18 months (The Economist, 1994). Hence, when output first begins to fall, unit labour costs rise faster because there is less production for the same amount spent on labour. The indicator is presented as index numbers and the interpretation is based on percentage change over a 12-month period.

4.6 Chapter summary

This chapter has discussed some basic principles of economic indicators involving their definitions, purpose and use, and methods of interpretation. At the same time, an overview of the major indicators of national output, population and employment, government fiscal policies, national consumption, investment savings, industry and commerce, trade and exchange rates, money and finance, and prices was provided. These form the essential background information on economic indicators required for this study.

First, definitions of indicators, economic indicators and the business cycle were provided in Section 4.2. Economic indicators were defined as descriptive and anticipatory data used as tools for business conditions analysis and forecasting. This definition was derived from the statistical concept of indicators and in relation to the business cycle.

Second, the purpose and uses of indicators and economic indicators were elaborated in Section 4.3. The general need for indicators was discussed in the context of statistics. More specifically, the purpose and uses of economic indicators were examined in relation to the business cycle. Primarily, they are used for predicting economic events that precede a recession. Such predictions would serve as warning signs of a forthcoming recession so that early actions can be taken to avoid or lessen any adverse effects.

Third, Section 4.4 examined some basic methods of interpreting economic indicators. They included: nominal and real terms; index numbers; net and percentage changes; growth rates; moving averages; and seasonality. These methods help to analyse figures of economic indicators by: revealing the effects of inflation; reflecting relative changes; revealing the underlying trend by smoothing out irregularities; and eliminating seasonal effects.
Finally, a list of major economic indicators was presented in Section 4.5. The indicators were grouped under various main headings and the information provided for each indicator relates to its scope, significance and interpretation. In the first group, indicators of national output comprised nominal and real GDP, GDP per head, productivity and cyclical or leading indicators. They are the most comprehensive indicators which reflect the state and composition of a country's overall economy. The second group consisted of vital indicators of population and employment. Essentially, they are reflective of an economy's long-term growth. Next, fiscal indicators, namely, public expenditure, government revenues and national debt, were described. Together, they are indicative of the fiscal activities of the government such as providing public services, redistributing incomes and influencing the overall level of economic activity. National consumption was the next group of indicators examined. The two related indicators described were personal and disposable incomes, and consumer expenditure or private consumption. Consumers play a vital role in a nation's economy since personal consumption accounts for between half and two-thirds of the GDP. The following group of indicators presented was national investment and savings. It comprised two main indicators: fixed investment and GDFCF; and national savings. The former is spending on physical assets such as infrastructure and buildings, while the latter measures total savings in an economy, that is, by the private sector and the government. Under the heading of industry and commerce, seven different indicators relating to various industrial and commercial sectors were elaborated. The main sectors covered were industrial and manufacturing, construction and house-building, and wholesale and retail. Next, the focus was on international trade. The indicators highlighted for trade and exchange rates were imports, exports, trade balance and nominal exchange rates. They are essential for monitoring a country's international trade and financial flows, and value of its currency in terms of other currencies. For the category of money and finance, four main indicators were described. They comprised money supply, bank lendings, interest rates, and stock and share prices. Together, they reflect the monetary policy adopted by the government for controlling the economy. The last group of indicators presented relates to prices. In essence, price indicators are direct measures of inflation, which is a vital factor to monitor and control. The price indices examined were the export and import price index, the property price index, the building material price index and the consumer price index. Other indicators described within this group were GDP deflator and unit labour costs.
CHAPTER 5

THEORETICAL IDENTIFICATION OF ECONOMIC INDICATORS FOR MODELING DEMAND FOR DIFFERENT TYPES OF BUILDING CONSTRUCTION

5.1 Introduction

As discussed in Chapter 3, determinants of demand are linked to the different needs for construction and are primarily influenced by economic and social factors. The objective of this chapter is to examine the nature of demand for different types of building construction and identify their associated economic and social factors.

Building construction can be classified in various ways depending on the level of detail required. Section 5.2 discusses the adoption of a specific classification for this study which categorises building construction as residential, industrial and commercial. Justifications for the choice are also given.

Sections 5.3, 5.4 and 5.5 deal, respectively, with the demand for residential, industrial and commercial buildings. For each type of demand, the characteristics and determinants of demand are examined, the economic and social factors often associated with demand are reviewed, and economic indicators that measure these factors are identified. Finally, Section 5.6 summarises the results of the theoretical identification of economic indicators for the three types of demand.

5.2 Classification of building construction

Various ways of classifying construction have been discussed in Section 3.4. Traditionally, the construction industry produces a wide variety of different types of construction. In order to treat them separately based on their individual unique characteristics, they have to be disaggregated according to the purpose that they were built for. This is to allow for statistical distinction in the compilation of national statistics for the construction industry, and to facilitate studies on demand and output as differing factors influence demand for different types of construction.
5.2.1 Classification adopted for this study

For the purpose of this study, building construction is classified as:

- Residential;
- Industrial; and
- Commercial.

This classification follows closely to the one adopted by Hillebrandt (1985), Briscoe (1988) and Ofori (1990). The only difference is that these writers considered industrial and commercial buildings as one category.

Regarding the scope of this adopted classification, a few salient points have to be addressed here. First, this study is concerned with the construction of buildings alone. Second, this study covers only new work; repair and maintenance work is excluded. Finally, within each category, there is no distinction between public and private sector work.

5.2.2 Justifications for choice

This classification is adopted for the study because of the following reasons:

1) The categories broadly classifies building construction into three distinct types, meeting the basic requirement for the examination and identification of differing economic and social factors influencing demand for different types of building construction; a more detailed classification is, therefore, not necessary.

2) Although past studies have typically considered industrial and commercial buildings as one category, the determinants of demand for industrial and commercial buildings were generally discussed separately and distinctly. Hence, this implies that it would be more appropriate to treat them as two distinct categories.

3) This chapter is linked to the next, which uses data of the Singapore construction industry to carry out quantitative analyses of its demand. In Singapore, national level statistics for building construction are categorised according to residential, industrial and commercial types. Therefore, in order to facilitate a direct application of the findings of this chapter to
5.3 Demand for residential buildings

5.3.1 Characteristics and determinants of demand

Residential construction is a vital sector of the national economy, accounting for 5 per cent of GNP, 30 per cent of fixed investment, and 3 per cent of the national labour force (Rosen, 1979). Housing, the product of the residential construction sector, is the single most important item of expenditure of an average household. The extreme cyclical volatility of new housing construction is a pervasive characteristic of the sector. Hence, residential construction plays an important role in efforts to stabilise the national economy. It tempers excess demand during periods of expansion, and often leads the economy-wide recovery from recession. However, the periodic cyclical declines in new housing construction are costly to both the construction industry and the society. Decline in production and employment in the residential construction sector results in both the industry operating below capacity and the rise in unemployment.

Demand for residential buildings is to a substantial extent determined by the need for new housing as a whole. Housing need is generally the main factor which creates housing demand. However, housing need is different from housing demand. The need only becomes an effective demand when it is accompanied by the ability to finance the purchase. In the longer term, the markets for new housing are created by the need for more houses than are currently available. Hence, the amount and condition of existing housing stock also influence the extent of this need.

The overall housing market can be divided into three distinct sub-markets: owner-occupied housing; public sector housing; and rented housing. Within each sub-market, there are also single and multi-family units. This heterogeneous characteristic of the housing market has created complexity and difficulty in estimating housing demand.

The provision of a satisfactory supply of housing is of great concern to any government. Determining the level of supply and demand in both the public and private sectors is a vital task for the government. Generally, there are several factors which affect demand for all types of housing. In the long term, the most important influences on the general demand for housing are: the size of population growth; the rate of household formation; the size of existing housing stock; and the rate
of economic growth. Effectively, the faster the rate of new household formation, the greater the demand for housing; and the higher the income earned in an expanding economy, the greater the demand for bigger and better houses owing to increasing standards of living.

5.3.2 A review of associated economic and social factors

The realisation that the housing cycle is costly to both the construction industry and the society has stimulated substantial research into the causes of short-run fluctuations and the factors that affect demand for housing construction.

Rosen (1979) focused his attention on the causes of cyclical fluctuations in residential construction, and in the process highlighted several important issues concerning housing demand. Firstly, he attributed the cyclical pattern of demand to the overwhelming dependency of housing on mortgage credit and to deficiencies in the housing finance system that provides mortgage credit. The high capital costs and the extreme durability of the housing product have made debt financing central to the housing market; the household must rely heavily on borrowed funds to purchase housing. Secondly, he emphasised the role of the supply of mortgage credit. He explained that the rationing or disequilibrium characteristic of the mortgage market is responsible for the difficulty in obtaining mortgages during periods of financial restraint. This happens when the supply of mortgage funds does not equal the demand for mortgage funds at the market interest rate. During these periods, many households are not able to obtain any mortgage at the quoted interest rate. The characteristic disequilibrium of the mortgage market has, in turn, led to a primarily institutional explanation for short-run housing cycles. Thirdly, he recognised the influence of the cost of mortgage funds on the housing cycle. He highlighted that housing and mortgage demand have traditionally been viewed as the most interest-rate sensitive sector of the economy and, hence, the movements of mortgage rate do influence demand and, in turn, affect the cycle. Fourthly, he considered savings deposits as a vital source of mortgage credit and the amount of deposits is a major determinant of the level of mortgage availability. Finally, he concluded that governments have made substantial attempts to moderate the fluctuations in new residential construction using public policy that regulates mortgage availability and cost.

Also pertaining to the residential building cycle, Hall and Richardson (1980) found that the major factor that affects builders' perception of demand is the number of loans made to first-time home purchasers. In turn, this depends on monetary issues such as average bank deposits, average mortgage repayment of first-time buyers and average income earnings.
Hillebrandt (1974), Ofori (1990) and Cherniavsky (1990) examined demand for housing at two different levels: basic and economic. The determination of the basic level of demand is based on the total need for new housing. Need is defined by Hillebrandt as the difference between an accepted standard of housing provision and the extent to which the stock reaches this standard. It is dependent on requirements for net new household formation; requirements to replace dwellings cleared in slum-clearance schemes and for other purposes such as road building; and requirements to increase the stock in relation to existing households to provide a margin of vacant dwellings for mobility. In short, the two main determinants of basic demand for housing are population factors such as, age structure, household formation and marriage rate; and characteristics of the existing housing stock. This need assessment assumes that certain standards of housing provision are to be achieved and these standards are often laid down by the government. In essence, this implies that the need-based approach is more applicable for determining demand for public housing. On the other hand, demand for private-sector housing is regarded as economic demand by the three writers. In this respect, economic factors play a more important role in influencing the level of demand. Hillebrandt cited personal disposable incomes; the level of unemployment; relative rates of increase in wages and salaries; supply of credit or savings; and changes in the rate of interest as the main determinants of demand for private housing. In addition, Ofori highlighted several other economic factors in his study of the Singapore residential market. They are: the prevailing property prices; the levels of housing provision by the public sector; and government incentives for private developers such as grants, subsidies or tax incentives. These factors were also cited by Cherniavsky in his study of effective or economic demand for private housing in Israel.

Some studies examined housing demand in general without making a distinction between the public and private sectors. Briscoe (1988) and Ruddock (1992) cited both economic and social factors as determinants of demand for overall residential construction. Firstly, household formation is considered as having a long-term influence over the demand for housing. Demand arises mainly from new marriages and also from their breakdown when households are split up. In addition, migration and immigration also affect demand as households move to another area to seek employment. Secondly, family income, both the amount of current and future expected, also determines a family's willingness to spend on housing. As incomes increase, it is generally the case that people are able to afford owner-occupied housing. Thirdly, the prices of houses also affect the type of housing demanded and the general level of demand. Rising house prices may cause people to look towards smaller property for purchase or even delay their purchases. Fourthly, the cost and availability of finance is again cited as an influencing factor as most households have to rely on a mortgage loan to finance their house purchase. Finally, other factors mentioned include the
distribution of income, the rate of economic growth and unemployment, size of housing stock, personal taste and preferences, and government intervention. Factors similar to these were also highlighted in an earlier study by the National Economic Development Office (1984) on the prospects for construction to 1990 in the UK. In relation to general housing demand, the influencing factors considered were new household formation rates, interest rates, real income growth, changing demographic and social trends, provision of credit finance, fiscal support, government spending and availability of financial incentives for housing. However, it was noted that with regard to owner-occupied or private housing, the two decisive factors are interest rates and growth of real incomes.

A few writers only focused their attention on the private housing market. In this respect, Stone (1983) only identified economic factors as having an influence over private housing demand and they consist of the rate of interest, the availability of mortgage, the rate of inflation, prices of property and the level of real income. Although Raftery (1991) also considered only private sector or owner-occupied housing demand, the influencing factors were not restricted to economic ones. They include: size and condition of existing housing stock; demographic change; the rate of real interest; and the level of household disposable income. Therefore, in essence, there is no clear distinction between the factors that affect public and private housing demand.

At a quantitative level, several studies were undertaken to model demand for residential construction based on economic and social factors. Tang et al. (1990) applied independent variables such as, national income per capita, relative price index, size of population, rate of household formation and interest rate in their model of Thailand's residential construction demand. However, the analysis found that household formation did not have a significant effect on demand and was excluded from the model. In another study, Akintoye and Skitmore (1994) tested the significance of some economic variables against private housing demand in the UK. They found that measures of construction price level, national output and real interest rates were suitable modelling variables, while those of unemployment and manufacturing profitability were insignificant. In a recent study of demand modelling for residential construction in Singapore, Goh (1996) identified several significant economic indicators that are related to demand. They are: GDP per capita; GFCF for construction and works; real GDP; building material price index; money supply (M2); money supply (savings and others); Central Provident Fund (CPF) withdrawal for home-ownership; prime lending rate; consumer price index; property price index for residential property; labour force; and unemployment rate. The indicators that were found to be insignificant are: number of marriages registered; number of planning approvals for residential projects; and total resident population.
5.3.3 Identification of economic indicators

Based on the economic and social factors highlighted as having an influence on demand for residential construction, economic indicators that measure these factors can be identified. Table 5.1 lists down these economic and social factors together with their corresponding economic indicators.

<table>
<thead>
<tr>
<th>Economic and Social Factors</th>
<th>Economic Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Economic growth</td>
<td>a) Real GDP; GDP per head; and Productivity</td>
</tr>
<tr>
<td>b) Cost of borrowing</td>
<td>b) Interest rate</td>
</tr>
<tr>
<td>c) Family formation</td>
<td>c) Household formation</td>
</tr>
<tr>
<td>d) Population size</td>
<td>d) Population</td>
</tr>
<tr>
<td>e) Property price</td>
<td>e) Property price index</td>
</tr>
<tr>
<td>f) Level of income</td>
<td>f) Disposable income; GDP per head; and Wages and earnings</td>
</tr>
<tr>
<td>g) Level of unemployment</td>
<td>g) Unemployment</td>
</tr>
<tr>
<td>h) Existing housing stock</td>
<td>h) Housing stock (Additions)</td>
</tr>
<tr>
<td>i) Government intervention</td>
<td>i) Planning approval issued</td>
</tr>
<tr>
<td>j) Rate of inflation</td>
<td>j) Consumer price index; and GDP deflators</td>
</tr>
<tr>
<td>k) Construction price</td>
<td>k) Building tender price index; and Building material price index</td>
</tr>
<tr>
<td>l) Mortgage credit availability</td>
<td>l) Money supply; National savings; and Bank lending</td>
</tr>
</tbody>
</table>
5.4 Demand for industrial buildings

5.4.1 Characteristics and determinants of demand

Demand for industrial buildings is not directly dependent on the ultimate consumer but on the producers of goods for the ultimate consumer. In essence, this is known as derived demand; demand for construction is derived from demand for other goods. It is governed by the acceleration principle which states that if demand for any consumption good increases, demand for investment goods used in its production will increase at a greater rate. For instance, when product sales are rising, firms anticipate continuing growth and so a derived demand for more factory space is created. Essentially, the accelerator principle operates because investment goods including buildings have a long life so that the stock constitutes a very important element in the total situation.

Hence, the main determinant of demand for industrial buildings is expectation of the future output of the goods manufactured in those buildings. The expectations of the manufacturer for future demand for the goods he produces are vital to the decision to use a new building, especially when the increase in demand for goods or the development of new processes cannot be housed in the existing buildings. Equally important are his expectations of future costs, since he is concerned to make a profit out of his investment in new buildings and works. However, the building itself is usually regarded as a small part of the total investment required for production; plant and machinery being normally more costly. Therefore, the need for investment in buildings may be less obvious and the advantages more difficult to quantify partly because the life of the building is long. Plant and machinery have a shorter pay-back period, thus producing less risk in their investment. Besides, investment in new buildings will only occur when other easier, quicker, less expensive or more reversible means, such as employing more workers, effecting further mechanisation, renting an existing building or renovating and refurbishing existing premises, have been exhausted or are inappropriate. These will be a preferred strategy where doubts exist about the permanence of any increase in product demand.

5.4.2 A review of associated economic and social factors

Demand for industrial buildings, as already discussed, is derived directly from demand for manufactured goods. Moreover, industrial buildings are regarded as investment goods and, most
often, are financed with borrowed capital. Hence, economic factors should play a more important role in determining their levels of demand. Most studies have focused on factors related to business conditions in the manufacturing sector and general conditions of the whole economy.

At the industry level, Hillebrandt (1974) explained that because of the close relationship between the level of industrial investment, the level of industrial production and the health of the economy, it would be expected that forecasts of the level of industrial building could be based on the level of industrial production and the GDP. Corresponding to this inference, Briscoe (1988) cited the UK manufacturing sector as an example. In the late 1980s, demand for many of the products produced by UK manufacturing firms has been weak and erratic. Export markets have been lost and in many cases, significant import penetration into domestic markets has meant reduced sales volumes for UK firms. Inevitably, such weaknesses in final demand have had a derived effect on the manufacturing sector's demand for industrial buildings.

At the enterprise level, Stone (1983) emphasized that demand for industrial buildings depends on business confidence and on the rate of innovation and change in business activities and location. Firms generally only require new and additional buildings when trade is buoyant and they feel confident enough about the future to re-equip or expand their business. Innovations and changes in business activities tend to result in both a demand for new buildings to meet changing technological requirements, and for additional buildings. Relocation from old to new towns and from one region to another also adds to demand for new industrial buildings. Similarly, Ofori (1990) stressed the influence of long-term business confidence and levels of local and international competition on the level of demand for industrial buildings.

In addition to factors determining the willingness to invest, Briscoe (1988) highlighted that the market for industrial buildings is also governed by factors controlling the firm's ability to finance their investment. Where high profits are being generated, there is availability of funds to accommodate such investment. Hence, the availability of internal funds, which tends to reduce the effect of interest rates on investment decisions, is an important factor. But, in the absence of such internal profits, firms must look for external sources of capital. When tight monetary policies are being operated, resulting in more strictly controlled bank loans and higher interest rates, they will serve to depress the market for industrial buildings, as new investment is delayed by unfavourable borrowing conditions. In most industrial establishments, buildings are usually a minor component of the total costs of investment. The availability of funds and interest rates are also important to the whole business investment since the investor requires considerably more capital than that required
for the cost of the building. Government intervention is also an important factor determining industrial building investment. Ofori (1990) noted that the industrialist or developer's decision to build is also affected by government's policies on investment, taxation, subsidies and controls.

More specifically, Killingsworth (1990) provided a list of determinants of demand for industrial construction in the United States identified by construction economic theory. Many of these factors have been discussed earlier. They are: population; interest rates; shocks to the economy; the demand for goods; the ability to meet demand through remodelling operations; government policy; surplus manufacturing capacity; the expectation of continued increased demand; the expectation of increased profits; and new technology. When these determinants were correlated with industrial construction, some were found to be insignificant and they are: population; surplus manufacturing capacity; the expectation of increased profits; and the expectation of continued increased demand. On the other hand, the three most significant determinants were found to be interest rates, economic shocks and the demand for goods. The remainder, such as technology and government policy, were not quantifiable. In another statistical study, Akintoye and Skitmore (1994) discovered that GNP and manufacturing profitability were significantly related to demand for private sector industrial construction in the UK, while real interest rate, unemployment and construction price were insignificant.

5.4.3 Identification of economic indicators

The review has highlighted the economic and social factors that have an influence on demand for industrial buildings. Table 5.2 summarises and lists these economic and social factors together with their corresponding economic indicators.
**Table 5.2 Factors and their corresponding economic indicators identified for industrial construction demand**

<table>
<thead>
<tr>
<th>Economic and Social Factors</th>
<th>Economic Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Business confidence</td>
<td>a) Business conditions</td>
</tr>
<tr>
<td>b) Level of export</td>
<td>b) Export of goods; Trade balance</td>
</tr>
<tr>
<td>c) Level of industrial production</td>
<td>c) Industrial and manufacturing production</td>
</tr>
<tr>
<td>d) National output/ Economic growth</td>
<td>d) Real GDP; GDP per head; and Productivity</td>
</tr>
<tr>
<td>e) International competitiveness</td>
<td>e) Exchange rates; Unit labour cost; Unit business cost; and Export price index</td>
</tr>
<tr>
<td>f) Population size</td>
<td>f) Population</td>
</tr>
<tr>
<td>g) Economic shocks</td>
<td>g) Cyclical or leading indicators</td>
</tr>
<tr>
<td>h) Government interventions</td>
<td>h) Government revenues</td>
</tr>
<tr>
<td>i) Level of demand for manufactured goods</td>
<td>i) Wholesale sales and orders</td>
</tr>
<tr>
<td>j) Level of profits</td>
<td>j) Capital expenditure intentions</td>
</tr>
<tr>
<td>k) Level of investments</td>
<td>k) Total investment</td>
</tr>
<tr>
<td>l) Expectation of increased demand for manufactured goods</td>
<td>l) Business expectation (manufacturing orders)</td>
</tr>
<tr>
<td>m) Credit availability</td>
<td>m) Money supply; National savings; and Interest rates</td>
</tr>
<tr>
<td>n) General economic conditions</td>
<td>n) Unemployment; and GDP deflators</td>
</tr>
</tbody>
</table>

**5.5 Demand for commercial buildings**

**5.5.1 Characteristics and determinants of demand**

The category of commercial building comprises a whole range of buildings including offices, hotels, shops and restaurants. Together they accommodate activities of the service and entertainment sectors of the economy. Since commercial building comprises a heterogeneous collection of
buildings, demand estimation is often complicated by the need to disaggregate them as different types of activities have different space requirements. A possible alternative is to identify only the common factors that affect all types of commercial buildings and use them to estimate the demand for commercial buildings as a whole.

Like industrial buildings, demand for commercial buildings is derived demand and similarly, the acceleration principle applies as well. But demand for commercial buildings is usually derived directly from demand for services rather than goods, as in the case for industrial buildings. Hence, the commercial requirement is for buildings of higher quality, reflecting the need for improved space and services provision. In addition, the location of the commercial building is often a critical consideration in making the decision to invest. Offices, shops and entertainment centres need to be located near urban centres, a fulcrum for service industry activity. Demand for new commercial accommodation mainly comes from growing or diversifying existing enterprises requiring additional space, newly formed companies, firms relocating from elsewhere, and redevelopment of existing commercial facilities.

Contrary to industrial buildings which are commissioned by the firms who intend to use them, the majority of commercial buildings are built speculatively by property developers and financial institutions. Generally, such properties are developed for rent, especially when the developers are confident of the future level of rents. When commercial rents are rising more rapidly than interest rates, commercial buildings are a favoured investment.

5.5.2 A review of associated economic and social factors

Similar with industrial buildings, demand for commercial buildings is derived demand. However, it is mainly derived from demand for services rather than manufactured goods, and industrial buildings are mostly commissioned by firms who intend to use them while commercial buildings are developed for speculative purpose or for rent. These main differences have generally distinguished the factors that affect the demand for industrial and commercial buildings.

Hillebrandt (1974) highlighted some differences between the factors that affect the demand for industrial and commercial buildings. First, the capacity of an office building or some other types of building is less rigid than that of factories. It is usually possible in the short run to squeeze in extra personnel and equipment by lowering space standards. Hence, demand for commercial buildings may be affected by space requirements to a lesser extent than that for industrial buildings. Second,
a good public image is more important to the commercial sector than the industrial sector, and commercial buildings such as hotels and shops may even be dependent on this for its profits. Therefore, demand for commercial buildings may be influenced, to a greater extent, by quality requirements than that for industrial buildings. However, she also cited several factors which affect demand for both categories of buildings such as the state of the economy, government policies, the expectations of output and profits, and the availability and cost of financing capital.

Stone (1983), on the other hand, considers the factors that affect demand for commercial and industrial buildings as similar. He maintains that demand for commercial buildings also depends on business confidence, the rate of innovation, the change in business activities, and location. However, he noted that the factors will differ in terms of the type of ownership. Factors which influence demand for owner-occupied properties differ from those which affect demand for properties developed for letting. Generally, properties are developed for rent when developers are confident of the adequacy of future returns from such investments. The higher the expected future level of rents, and this expectation rises with business confidence and anticipated inflation, the higher the level of costs that developers can contemplate meeting. In other words, they would be more prepared to pay for steeper land price or higher cost of borrowing. Therefore, for these developers, their demand for new commercial and industrial buildings depends on rising rent expectations, adequate and cheap credit in relation to rates of inflation, and favourable taxation. Essentially, these factors relate to government policy such as rent and credit restrictions, taxation and development control. In turn, they are also linked to the general economic environment. If these expectations are not fulfilled, development activity, especially in the commercial sector, is likely to be reduced since the majority of commercial buildings are built for sale or letting.

Government policy is also cited by Briscoe (1988) as one of the central restraints on the market for commercial buildings. He emphasized the importance of development control policy such as the availability of suitable sites and the granting of planning permission. As almost all commercial construction takes place in urban centres, not all proposed commercial developments can expect to obtain the required planning permission. Some developments may be significantly delayed by the process of obtaining planning approval. Such delays may be detrimental to the investment as profit margins will be reduced owing to the loss in rents and the extended period of capital repayment.

Ofori (1990) also viewed commercial buildings as a popular investment among private developers in many countries. Hence, speculation plays a large part in the decision to invest, since these
buildings are mostly owned by organisations or individuals other than the users. In other words, such investments are motivated solely by profit, which implies that the cost of investment has to be low while rental returns have to be high in order to maximise profits. In this highly competitive rental market, aspects of a building that help to sell it are important. Obsolescence is rapid as buildings incorporating features that make users' operations more efficient, occupiers more comfortable and the buildings themselves more efficient to run, tend to attract tenants. Government policy such as planning controls and regulations are also highlighted as crucial factors which affect the price of land. The decision to invest may depend on the cost of land, which can be high especially in the city centres. Another important factor cited was foreign capital. This may come in the form of foreign investments in the commercial sector. Two other economic factors highlighted were the potential retail trade volumes for shops, and changes in office-oriented employment based on forecasts of economic growth or projections of population growth for offices.

The study by Akintoye and Skitmore (1994) indicated that private sector commercial construction trends in the UK can be explained by the trends in real interest rate, manufacturing profitability, GNP and unemployment level. A model was developed based on these factors and was found to satisfy both theoretical and statistical requirements.

5.5.3 Identification of economic indicators

Several economic and social factors that affect demand for commercial buildings have been highlighted in the review. Table 5.3 compiles a list of such economic and social factors together with their corresponding economic indicators.
Table 5.3 Factors and their corresponding economic indicators identified for commercial construction demand

<table>
<thead>
<tr>
<th>Economic and Social Factors</th>
<th>Economic Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) State of the economy</td>
<td>a) Real GDP; Unemployment; Leading indicators; and GDP deflators</td>
</tr>
<tr>
<td>b) Cost of land</td>
<td>b) Commercial land values</td>
</tr>
<tr>
<td>c) Expectations of profits</td>
<td>c) Business conditions; Retail sales; Property rental values; Property price index; and Tourist arrivals</td>
</tr>
<tr>
<td>d) Availability of credit</td>
<td>d) Money supply; and National savings</td>
</tr>
<tr>
<td>e) Cost of borrowing</td>
<td>e) Interest rate</td>
</tr>
<tr>
<td>f) Development control</td>
<td>f) Planning approvals issued</td>
</tr>
<tr>
<td>g) Foreign capital</td>
<td>g) Foreign investment</td>
</tr>
<tr>
<td>h) Population size</td>
<td>h) Population</td>
</tr>
<tr>
<td>i) Economic growth</td>
<td>i) Real GDP; GDP per head; and Productivity</td>
</tr>
<tr>
<td>j) Change in office-oriented employment</td>
<td>j) Employment</td>
</tr>
<tr>
<td>k) Total cost of development</td>
<td>k) Fixed investment</td>
</tr>
</tbody>
</table>

5.6 Summary of theoretical identification results

Many economic and social factors that influence demand for different types of building construction have been theoretically reviewed in the preceding sections. As there is a need to quantify and measure these qualitative factors, economic indicators that correspond to them have been identified. Table 5.4 summarises the results of the theoretical identification of economic indicators for residential, industrial and commercial building construction demand.
<table>
<thead>
<tr>
<th>Type of Demand</th>
<th>General Characteristics of Demand</th>
<th>Economic Indicators Identified</th>
</tr>
</thead>
</table>
| Residential building | 1) Demand for new housing construction is subject to extreme cyclical fluctuations.  
2) Housing is generally regarded as a consumption good and is the largest single item bought by households which is financed mainly by mortgage credit.  
3) Housing need is the basic determinant of demand. | 1) Real GDP  
2) GDP per head  
3) Productivity  
4) Interest rate  
5) Household formation  
6) Population  
7) Property price index  
8) Disposable income  
9) Wages and earnings  
10) Unemployment  
11) Housing stock (Additions)  
12) Planning approval issued  
13) Consumer price index  
14) GDP deflators  
15) Building tender price index  
16) Building material price index  
17) Money supply  
18) National savings  
19) Bank lending |
| Industrial building | 1) Demand for construction is derived from demand for manufactured goods and is governed by the acceleration principle.  
2) Industrial buildings are regarded as investment goods.  
3) The main determinant is the expectation of the future output and demand for manufactured goods. | 1) Business conditions  
2) Export of goods  
3) Trade balance  
4) Industrial and manufacturing production  
5) Real GDP  
6) GDP per head  
7) Productivity  
8) Exchange rate  
9) Unit labour cost  
10) Unit business cost  
11) Export price index  
12) Population  
13) Cyclical or leading indicators  
14) Government revenues  
15) Business expectation (manufacturing orders)  
16) Wholesale sales and orders  
17) Capital expenditure intentions  
18) Total investment  
19) Money supply  
20) National savings  
21) Interest rate  
22) Unemployment  
23) GDP deflators |
| Commercial building | 1) Demand for construction is derived mainly from demand for services and is governed by the acceleration principle.  
2) This category of buildings comprises a heterogeneous collection of buildings such as offices, shops and hotels.  
3) Commercial buildings are mainly regarded as speculative investments which are built for sale or letting. | 1) Real GDP  
2) Unemployment  
3) Leading indicators  
4) GDP deflators  
5) Commercial land values  
6) Business conditions  
7) Retail sales  
8) Property rental values  
9) Property price index  
10) Tourist arrivals  
11) Money supply  
12) National savings  
13) Interest rate  
14) Planning approvals issued  
15) Foreign investment  
16) Population  
17) GDP per head  
18) Productivity  
19) Employment  
20) Fixed investment |

Footnote: The economic indicators are not ranked in any order of importance.
5.7 Chapter summary

This chapter has reviewed, theoretically, the economic and social factors that affect demand for different types of building construction. Correspondingly, economic indicators have been identified for these factors. Together, they form a list of theoretical indicators which will be statistically examined in the Chapter 6.

Section 5.2 reiterated the need to classify construction and then, for the purpose of this study, categorised building construction as residential, industrial and commercial. Justifications for the choice were given.

Demand for residential building construction was examined in Section 5.3. The main characteristics and determinants of this type of demand were discussed to serve as background information. In short, it covered issues related to the cyclical volatility of new housing construction; the derivation of effective housing demand from housing need; the various sub-markets of the overall housing market; and the main factors which influence public and private housing. Next, a theoretical review of the economic and social factors that affect demand for residential construction was provided. It highlighted the factors examined and discerned by various writers as having an impact on housing demand levels. In order to measure these factors, economic indicators were identified correspondingly. The results of this identification were listed in Table 5.1.

The same process was carried out for industrial and commercial buildings. Section 5.4 examined the demand for industrial buildings in relation to its characteristics and determinants; the associated economic and social factors; and their corresponding economic indicators. Demand for industrial buildings is derived from the demand for manufactured goods. Hence, the expectation of future output and demand for manufactured goods is considered as the main determinant of demand for industrial buildings. As these buildings are generally regarded as investment goods, economic factors were mainly cited as having an effect on demand levels. The associated economic indicators were identified and listed in Table 5.2.

Demand for commercial buildings was discussed in Section 5.5. Similarly, the nature of demand for commercial buildings is derived demand. However, it is mainly derived from the demand for services rather than manufactured goods. The category of commercial building comprises a
collection of buildings, namely, offices, shops and hotels, and factors that affect each type of commercial buildings differ. Hence, only the common factors can be used to estimate demand for such buildings. Most commercial buildings are built for speculative purposes such as sale or letting. Hence, investment profits from sale or rental were viewed as the main determinant of demand for construction. Owing to this investment nature, economic factors also play a vital role in influencing demand levels. Table 5.3 produced a list of economic indicators corresponding to these factors.

Finally, the overall results of the theoretical identification of economic indicators for residential, industrial and commercial buildings were summarised in Table 5.4. It also provided a summary of the main characteristics of demand for these types of buildings.
6.1 Introduction

In the preceding chapter, a theoretical identification of economic indicators for modelling demand for different types of building construction has been carried out. This chapter takes a step further by imposing several forms of statistical selection criteria on these indicators to obtain a set of indicators that satisfies the economic significance and statistical adequacy criteria.

For any type of statistical study, data procurement plays an important part in determining the accuracy of the analysis. Hence, Chapter 6 begins by discussing the critical items in data procurement such as data source, sample size and sample frequency in Section 6.2. This being a case study of Singapore, Section 6.2.1 reviews its current statistical system and the major statistical activities in the public sector which is primarily responsible for compiling national level statistics. The sample size and frequency used for the study are elaborated in Section 6.2.2.

In Section 6.3, the methodology adopted for data transformation and statistical selection of indicators is explained in separate sub-sections. Section 6.3.1 focuses on the various types of data preprocessing or adjustments that are necessary to make them more suitable for modelling purposes. This is followed by a more rigorous discussion of two popular variable selection procedures in Section 6.3.2. It also examines the use of different levels of statistical significance in these procedures.

Owing to the differences in terminology between theory and statistics, Section 6.4 elaborates on the identification of national level statistics that are equivalent to the theoretical indicators. The three different types of building construction namely, residential, industrial and commercial are discussed in this respect separately under Section 6.4.1, 6.4.2 and 6.4.3.

Following the application of the various Stepwise Regression selection procedures, the results are given in Section 6.5. Again, discussions for different types of building construction are carried out separately under Section 6.5.1, 6.5.2 and 6.5.3. An integration of these discussions is achieved in
Section 6.6 with a summary of the statistical selection results. It provides a list of theoretically significant and statistically adequate indicators for each type of building construction.

Finally, the chapter concludes with Section 6.7 which provides a general discussion of the findings of the statistical selection procedures. Justifications are given, in Section 6.7.1, for any disparity found between the theoretical identification and the statistical selection of significant indicators of construction demand. The choice of a final list of variables for modelling residential construction demand is elaborated in Section 6.7.2.

6.2 Data collection

Data procurement is the first, and perhaps the most important, stage in any statistical study. Before it can be properly carried out, decision has to be made on two critical aspects. Firstly, the data source has to be established; and secondly, the sample size and frequency have to be determined.

6.2.1 Source of data

There are two main sources of data, primary and secondary. Primary data sources include all forms of original collection of data. Such data are more expensive to obtain than data from secondary sources, but can be designed to fit a particular study requirement. Some alternative methods to collect primary data include sampling procedures, continuous surveys, or a complete census covering the items of interest. Secondary data sources is synonymous to published data sources. Data are collected and published by independent organisations such as government ministries, non-profit institutions and international research companies. Hence, secondary data sources are often the easiest source of data to deal with and usually the cheapest. Their two major drawbacks are that they are geared towards specific requirements which may not fit those of interest; and the reliability of the data depends on the credibility of the publishing organisation.

Owing to the nature of this study, which requires access and manipulation of a vast quantity of industry and government statistics, the choice of secondary data sources is necessary. To date, several organisations have been collating and publishing economic and social statistics of Singapore, and they are: The Department of Statistics, Ministry of Trade and Industry; the Economist Intelligence Unit; and the International Monetary Fund Statistics Department. The first is a government agency, while the second and third are independent research organisations. The
Department of Statistics, being a government agency, is able to provide a more comprehensive set of economic and social statistics than the two private organisations. Hence, the governmental source is used to meet the requirement of the study and, that is, to involve as many economic and social indicators as possible in order to make a more exhaustive effort to select indicators that are significantly related to construction demand. Cross-checks are made against the two private data sources for some key statistics so as to validate the governmental source.

Following the choice of a suitable data source, a brief account of the statistical system of Singapore and the major statistical activities of its public sector is provided in the following sections.

6.2.1.1 The statistical system of Singapore

The statistical system of a country refers to the organisation of the national official statistical activities of the country (Saw, 1981). The paramount aim of any statistical system is to generate timely, accurate and comprehensive statistics that can be of immediate use to administrators, policy-makers and research personnel in both public and private sectors.

A formal system for the collection of official statistics has been in existence in Singapore as early as 1921 when a Statistical Bureau was established. For the next fifty years, the statistical system remained largely centralised, with a single organisation responsible for all statistical activities. After Singapore achieved independence in 1965, the statistical system was structurally transformed. The statistical collection mechanism has been decentralised and official statistics are currently collected and compiled by a large number of statistical agencies as well as government departments and statutory boards.

The evolution of Singapore's statistical system can be examined in four phases. They are the colonial period prior to 1959, the 1960s when Singapore achieved independence, the 1970s which witnessed Singapore's entry into the industrial age, and the 1980s in which Singapore joined the ranks of the newly developed countries. During the first phase, there was limited scope of statistical activities as Singapore's statistical system comprised a single centralised statistical organisation administered by the Department of Statistics. Expansion of statistical activities only took place in the 1960s in response to the increased demand for statistics. The expansion and diversification of the economic activities to include manufacturing, commerce and services necessitated the collection of a wider range of statistics. The rapid expansion of the activities and responsibilities of the Department of Statistics brought about a review of the statistical system. In the early 1970s, a
decentralised statistical system was adopted and implemented. A research and statistics section was set up in each of the four Ministries namely, Labour, National Development, Education and Health which have statistical activities that are sufficiently complex, plentiful, specialised and nationally important to warrant the establishment of a separate statistical system within each of them. In the 1980s, there was a further rationalisation and decentralisation of statistical activities in Singapore. The collection, compilation and publication of statistics for particular areas or sectors were transferred from the Department of Statistics to several other public-sector organisations which have administrative responsibility over those areas or sectors. However, in order to ensure that the decentralisation would not adversely affect the efficiency of data analysis and dissemination, a system of co-ordination was put in place. Co-ordination was essential to minimise duplication of efforts in data collection, facilitate optimal allocation of resources, ensure a high standard of statistical work and improve the efficiency and effectiveness of statistical activities and projects. The Department achieves these objectives by monitoring the statistical activities, promoting national statistical standards and administering statistical staff development. As the national statistical authority, the Department of Statistics remains responsible for the establishment and management of the national statistical information system. As the custodian of Singapore official statistics, the Department is responsible for collating and disseminating statistical information to the general public.

Over the years of statistical development in Singapore, a few pertinent issues have arisen and were highlighted by Cheung (1994) as follows:

1) **Decentralisation of statistical activities**

   The decentralisation of statistical activities in Singapore has benefited users of statistics in the last two decades. Firstly, there is closer contact and greater interaction between statistical personnel and data users in specific ministries and statutory boards, leading to more relevant statistics being collected and compiled. Secondly, specialisation of statistical personnel in specific subject matters enhances the quality and timeliness of the statistical series. However, there is a limit to further extension of decentralisation as there is also a need to guard against over-burdening of respondents through multiple data collection activities by different public-sector agencies.

2) **Integrity of official statistics**

   With the increasing sophistication of data users, official statistics are open to greater public scrutiny than before. Government statistical agencies have the responsibility to
maintain a high professional standard in order to ensure the integrity of official statistics and public confidence in the statistics. It is important that these agencies conform to international statistical standards and practice, and adopt sound statistical techniques and methodologies. In recent years, the Department of Statistics has taken steps to provide users with better understanding of the integrity and validity of its statistical series. Basic concepts and statistical methods are explained and made public through feature articles in the Department's quarterly bulletin.

3) **Maximisation of returns to statistical system**

Given the rapid changes in Singapore's society and economy, government statistical agencies need to constantly monitor and review the statistics collected to ensure their relevance and hence maximise returns to the statistical system. These agencies need to anticipate and keep track of new areas of interest and concern, and changes in data needs and allocate resources to critical areas. At the same time, they have to review current statistical priorities and focus on improving cost-effectiveness of existing data collections.

4) **Public concerns**

Over the years, the changes in Singapore's socio-economic conditions and increasing complexity of government administrative functions have generated new demands for statistics. The consequent increase in number of surveys conducted, survey frequency and number of items collected have raised concerns over the burden imposed on the population and business community. It is therefore essential to balance increasing and more diverse needs for statistics on the one hand, and the need to reduce public burdens on the other. Greater efforts would have to be expended to simplify existing surveys and rationalise data collection activities.

6.2.1.2 Major statistical activities in the public sector

Statistical activities in the public sector of Singapore have expanded considerably in recent years. New statistical series have been introduced and the frequency of some existing series has been increased to meet the growing needs of policy-makers for more information to support decision-making. The scope of statistical activities has also expanded beyond the collection, processing, compilation and dissemination of statistics to cover more analytical studies.
The Department of Statistics, and the Research and Statistics Units are the major statistics agencies in the public sector. Statistical activities are also undertaken by many government departments and statutory boards. The following is a summary of the statistical activities of the Department of Statistics, government ministries and statutory boards.

1) Department of Statistics

As the central statistical authority, the Department is responsible for the provision of aggregate statistics on the economy and the general population. Its major work areas include macro-economic accounts, economic surveys, manpower and socio-demographic statistics, and consumer and wholesale price indices.

2) Government ministries

There are eight government ministries in Singapore namely, Ministry of Community Development, Ministry of Education, Ministry of the Environment, Ministry of Finance, Ministry of Health, Ministry of Home Affairs, Ministry of Labour and Public Service Commission. Various departments in each of these ministries undertake statistical data collection and compilation from administrative records pertaining to their area or sector. For instance, the Ministry of Community Development is responsible for the collection of statistics on marriages and divorces while the Ministry of Finance handles statistical information on customs and excise duties, government operating revenue, government operating and development expenditures, and government debt.

3) Statutory boards

There are altogether 23 statutory boards in Singapore and the main ones include the Civil Aviation Authority of Singapore, the Construction Industry Development Board, the Economic Development Board, the Inland Revenue Authority of Singapore, the Monetary Authority of Singapore, the National Productivity Board, the Port of Singapore Authority, the Post Office Savings Bank, the Singapore Tourist Promotion Board, the Trade Development Board and the Urban Redevelopment Authority. Again, these statutory boards are responsible for the collection and compilation of statistical information in their specialised area of work. The range of statistical information produced by these agencies include price indices, volume of activities such as trade, services and construction, national
productivity levels, tourist arrivals, and monetary issues. Some of these agencies, such as the Monetary Authority of Singapore, supply data to the Department of Statistics for compilation and publication, while others are responsible for the dissemination of information themselves.

6.2.2 Sample size and frequency

The sample size and frequency are the next important aspects to be considered in the study. In the context of data requirements for forecasting methods, Makridakis et al. (1983) stressed that increasing the amount of data will generally increase the accuracy of forecasts, but not necessarily in direct proportion to the amount of data. In studies where macroeconomic data are used, the choice of the observation frequency plays a vital part in determining the sample size. For instance, the decision to use quarterly data, instead of annual data, increases the sample size by four times. Hence sample size and frequency are two interrelated factors, decision on one directly determines the other.

In this study, it has been decided that a larger sample size is preferred. The intention is to allow improvements in the accuracy of the forecasts and also to lessen the effects of multicollinearity. Therefore, quarterly data of the theoretical indicators are abstracted from statistical yearbooks, in the form of national level statistics, to create the time-series dataset. The collected data date from the first quarter of 1975 to the first quarter of 1994, which in total comprise 77 quarterly records over a span of 20 years. This time period is chosen because, firstly, data published before 1975 are not complete for most of the indicators, and secondly, data after the first quarter of 1994 were not yet published at the point of data collection. Once the collection process is completed, the data are entered into a computer database for statistical analysis to be carried out.

6.3 Methodology adopted for statistical selection

In many cases, it is necessary to preprocess or adjust the data after they have been collected in order for them to become suitable for quantitative analysis. Most adjustments involve modifications of the data to eliminate part of the information contained in the raw data. It is only after this stage that variable selection procedures are applied to the adjusted dataset. The methodology adopted for these stages is elaborated in the following sub-sections.
6.3.1 Data transformations

The first step of data modification involves transforming current price data into constant prices using a deflator index namely, the GDP deflators (base year 1990). As in many instances, accounting data are recorded in terms of current prices and thus reflect both inflation and real growth or decline in that item. This transformation allows the time series to be examined without being biased by inflation.

The second step of data preprocessing entails the disaggregation of annual time series to quarterly figures. This is necessary because most of the macroeconomic data are reported either quarterly or annually and it poses a difficulty when several time series have to be analysed jointly if their observation frequencies are not consistent. The need also arises when there is a change in the observation frequency in the same series. For example, a time series has been observed annually over several years and because of its increasing importance, the reporting agency decided to observe and release quarterly figures instead. This brings about a time series with annual observation in the first portion and quarterly figures in the remainder. Hence, a reasonable action is to disaggregate the annual time-series data to quarterly figures, instead of aggregating quarterly series to yearly totals which leads to a considerable loss of information. In a recent study (Chan, 1993), several prominent methods of disaggregating annual time series were described and their performances compared. Among the six methods examined, the INTER procedure was one of the two that gave satisfactory disaggregation results. This procedure is, therefore, chosen for the study and applied to the annual time series in the dataset. The following is a brief description of the INTER procedure.

The procedure is developed by Almon (1988) which provides a method to convert annual series to quarterly figures by interpolation. The annual time series \( Y_T \) is first cumulated to \( Z_T \) i.e.

\[
Z_T = \sum_{i=1}^{r} Y_i
\]

A cubic polynomial is fitted to each successive set of four points of \( Z_T \). The values of the polynomial are calculated at the ends of the quarters and these values are differenced to give quarterly series consistent with the yearly aggregates. For example, disaggregating \( Y_T \) to four quarterly values involves, firstly, a cubic polynomial \( p(T) \) is fitted to \( Z_1, Z_2, Z_3, \) and \( Z_4, \) and secondly, \( p(2), p(2.25) \),
\( p(2.5), p(2.75) \) and \( p(3) \) are computed. The quarterly figures are then obtained by \( p(2.25) - p(2), \)
\( p(2.5) - p(2.25), \ldots, p(3) - p(2.75) \), respectively. The sum of these quarterly figures is \( p(3) - p(2) = Z_3 - Z_2 = Y_3 \).

The fitting of a cubic polynomial to four successive points of \( Z_r \) produces the following equation in matrix format:

\[
A \times = b
\]

\[
\begin{bmatrix}
1 & 1 & 1 & 1 \\
1 & 2 & 4 & 8 \\
1 & 3 & 9 & 27 \\
1 & 4 & 16 & 64
\end{bmatrix}
\begin{bmatrix}
a \\
b \\
c \\
d
\end{bmatrix}
=
\begin{bmatrix}
Z_1 \\
Z_2 \\
Z_3 \\
Z_4
\end{bmatrix}
\]

In order to solve for \( a, b, c \) and \( d \), the inverse of matrix \( A \) is calculated as:

\[
A^{-1} = 
\begin{bmatrix}
4 & -6 & 4 & -1 \\
-4.33 & 9.5 & -7 & 1.83 \\
1.5 & -4 & 3.5 & -1 \\
-0.167 & 0.5 & -0.5 & 0.167
\end{bmatrix}
\]

and, the equation becomes:

\[
x = A^{-1}b
\]

By substituting values of \( Z_r \) and the inverse matrix into the above equation, values of \( a, b, c \) and \( d \) are calculated for each successive set of four points of \( Z_r \). As elaborated earlier, the quarterly figures are obtained by computing the \( p(T) \) values and then differencing them.
The third step of data adjustment involves the application of moving averages to eliminate seasonality and randomness from the data series. As the study uses quarterly time series, a centered four-quarter moving average is undertaken. First, a four-quarter moving average is calculated by adding the first four figures in the time series and dividing the total by four. Second, each successive average is obtained by dropping the first figure included in the previous average and adding the next figure in the series to derive the new average. In order to obtain an average corresponding to one of the time periods in the original series, a centered moving average is carried out by computing a two-period moving average of the moving averages that have been calculated previously. This smoothing method effectively removes seasonal variations from the data and, at the same time, cancels the effects of irregular factors. It helps to bring the data series to a more stable state, revealing its basic underlying pattern, where it can be examined more efficiently without the interference of short-term fluctuating components. However, this transformation is only applicable to time series that have been, in the first instance, recorded quarterly; those derived from disaggregating annual time series are excluded as they do not, originally, contain any quarterly seasonal factors.

6.3.2 The use of variable selection procedures

For any given number of independent variables, a variable selection procedure should provide the subset which its estimated equation produces the best fit, that is, the subset which its estimated equation produces the minimum residual sum of squares or, equivalently, the maximum coefficient of determination, known as the R-square. The variable selection methods adopted in the study are namely, the Stepwise Selection and the Forward Selection. In short, these methods adopt the principles of least squares regression. They have been regarded as the most practical least squares selection procedures among all other regression methods (Draper and Smith. 1981). Their basic steps are outlined below.

The Forward Selection method begins by finding the variable that produces the optimum one-variable subset, that is, the variable with the largest R-square. In the second step, the procedure finds the variable which, when added to the already chosen variable, results in the largest reduction in the residual sum of squares or increase in R-square. The third step finds the variable which, when added to the two already chosen, gives the minimum residual sum of squares or largest increase in R-square. The process continues until no variable considered for addition to the model provides a reduction in sum of squares considered statistically significant at a level specified at the start of the procedure.
The Stepwise Selection procedure begins like the Forward Selection, but after each new variable has been added to the model, the resulting equation is examined to check if any of the earlier introduced variables might conceivably have to be removed in order to give a better R-square result. The process of looking for the next best variable to include, and checking to see if previously included variable should be removed, is continued until certain criteria are satisfied, such as an earlier specified significance level. When it is no longer possible to find any new variable that contributes significantly to the R-square, or if no variable needs to be removed to improve on the current R-square, then the iterative procedure stops.

The choice of significant levels to be used in variable selection procedures plays a crucial part in determining which variables would be included in the subset. In short, a higher significance level such as, 95 per cent (p-value = 0.05), permits lesser variables into the subset than a lower significance level such as, 90 per cent (p-value = 0.10). Hence, it may be feasible to specify a few different levels of significance for each method to obtain a range of possible subsets. In relation to the specification requirements of the Forward Selection method and the Stepwise Selection method, there are two main differences. First, as the latter operates by selecting as well as removing variables from its model, it requires a specification of the entry and the exit levels; the former only requires an entry level to be specified. It is possible to use different levels for the entry and exit, but the entry level should always be set smaller than the exit level so that variables just entered would not be immediately rejected. Second, the default entry level recommended for the Forward Selection method is 0.50, while the entry and exit levels for the Stepwise Selection are 0.10 and 0.15, respectively (Freund and Littell, 1986). In order to experiment with different levels of significance, the ones chosen for each method are given in Table 6.1.

<table>
<thead>
<tr>
<th>FORWARD SELECTION</th>
<th>STEPWISE SELECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry (0.05)</td>
<td>Entry (0.05); Exit (0.10)</td>
</tr>
<tr>
<td>Entry (0.10)</td>
<td>Entry (0.10); Exit (0.15)</td>
</tr>
<tr>
<td>Entry (0.50)</td>
<td></td>
</tr>
</tbody>
</table>

Between the two methods, the Stepwise Selection is considered a more stringent variable selection procedure. This is because there exists a checking mechanism within the procedure which ensures
that the subset of variables selected at every stage is optimum: variables not contributing significantly to the R-Square are removed. In the case of the Forward Selection method, once a variable has been selected, it stays in the model. Hence, it can be implied that the Stepwise Selection procedure generally selects a smaller subset of variables than the Forward method. Perhaps, this may help to justify the choice of these two methods for the study. The idea of choosing a stringent method and a less restrictive one is to allow these procedures to select different possible subsets of variables, ranging from the smallest to the largest. The largest subset can serve to provide insights into the degree of consensus between theoretical deduction and statistical analysis. As these economic indicators have been theoretically identified beforehand, being statistically selected again proves stronger their relationship with construction demand. However, for forecasting purposes, it is often not advisable to use too many explanatory variables as the phenomenon of overfitting may occur, giving rise to poor predictive ability of the model. Although the use of more variables improves the model's fit to past data, forecasting performance on new data would actually deteriorate. Besides, a model containing a large number of independent variables generally produces the problem of multicollinearity. A high degree of multiple correlation among several independent variables occurs because as more variables are included in the model, there is a greater likelihood of some of them measuring similar phenomena. It often results in coefficient estimates that are not statistically significant or have incorrect signs or magnitude (Myers, 1986).

6.4 Theoretical and statistical classification of economic indicators

In Chapter 5, several economic indicators have been theoretically identified as related to residential, industrial and commercial building construction demand. Owing to the differences in terminology between theory and statistics, the process of data abstraction from statistical yearbooks requires the identification of their equivalent national level statistics. The following sub-sections elaborate on the national level statistics that are used to represent each of these indicators.

6.4.1 Demand for residential building construction

The national level statistical series chosen to represent demand for residential building construction is "Gross floor area of residential developments commenced". An alternative series, "Gross fixed capital formation for residential buildings", is also considered. The theoretical indicators, together with their equivalent national level statistics for residential building construction demand are listed in Table 6.2.
Table 6.2 National level statistical series for indicators of residential construction demand

<table>
<thead>
<tr>
<th>Theoretical Indicators</th>
<th>National Level Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>GDP at 1990 market prices</td>
</tr>
<tr>
<td>GDP per head</td>
<td>Per capita GDP</td>
</tr>
<tr>
<td>Productivity</td>
<td>Productivity growth</td>
</tr>
<tr>
<td>Interest rate</td>
<td>Prime lending rate (per S$1000)</td>
</tr>
<tr>
<td>Household formation</td>
<td>Number of marriages registered</td>
</tr>
<tr>
<td>Population</td>
<td>Size of population</td>
</tr>
<tr>
<td>Property price index</td>
<td>Residential property price index (base yr 1990=100)</td>
</tr>
<tr>
<td>Disposable income</td>
<td>Taxpayers, assessed income and tax assessed</td>
</tr>
<tr>
<td>Wages and earnings</td>
<td>Average monthly earnings</td>
</tr>
<tr>
<td>Unemployment</td>
<td>Unemployment rate</td>
</tr>
<tr>
<td>Housing stock (Additions)</td>
<td>Gross floor area of residential developments completed</td>
</tr>
<tr>
<td>Planning approval issued</td>
<td>Gross floor area of residential developments granted planning approval</td>
</tr>
<tr>
<td>Consumer price index</td>
<td>Consumer price index (base yr Sep87-Aug88=100)</td>
</tr>
<tr>
<td>GDP deflators</td>
<td>GDP deflators (base yr 1990=100)</td>
</tr>
<tr>
<td>Building tender price index</td>
<td>Building tender price index (base yr 1990=100)</td>
</tr>
<tr>
<td>Building material price index</td>
<td>Building material price index (base yr 1985=100)</td>
</tr>
<tr>
<td>Money supply</td>
<td>Money supply (M2)</td>
</tr>
<tr>
<td>National savings</td>
<td>Money supply (Savings &amp; other deposits)</td>
</tr>
<tr>
<td>Bank lending</td>
<td>Bank's loans &amp; advances (Housing loans)</td>
</tr>
</tbody>
</table>

6.4.2 Demand for industrial building construction

The national level statistical series used to represent demand for industrial building construction is "Gross floor area of industrial developments commenced". Table 6.3 lists the theoretical indicators and their equivalent national level statistical series.
Table 6.3 National level statistical series for indicators of industrial construction demand

<table>
<thead>
<tr>
<th>Theoretical Indicators</th>
<th>National Level Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business conditions</td>
<td>Business expectations in the manufacturing sector</td>
</tr>
<tr>
<td>Export of goods</td>
<td>Export of manufactured goods</td>
</tr>
<tr>
<td>Trade balance</td>
<td>Trade balance</td>
</tr>
<tr>
<td>Industrial and manufacturing production</td>
<td>Total manufacturing output</td>
</tr>
<tr>
<td>Real GDP</td>
<td>GDP at 1990 market prices</td>
</tr>
<tr>
<td>GDP per head</td>
<td>Per capita GDP</td>
</tr>
<tr>
<td>Productivity</td>
<td>Productivity growth</td>
</tr>
<tr>
<td>Exchange rate</td>
<td>Exchange rate, average of period</td>
</tr>
<tr>
<td>Unit labour cost</td>
<td>Unit labour cost index of manufacturing (base yr 1988=100)</td>
</tr>
<tr>
<td>Unit business cost</td>
<td>Unit business cost index of manufacturing (base yr 1988=100)</td>
</tr>
<tr>
<td>Export price index</td>
<td>Export price index (base yr 1990=100)</td>
</tr>
<tr>
<td>Population</td>
<td>Size of population</td>
</tr>
<tr>
<td>Cyclical or leading indicators</td>
<td>Composite leading index (base yr 1985=100)</td>
</tr>
<tr>
<td>Government revenue</td>
<td>Government rates and fees index of manufacturing (base yr 1988=100)</td>
</tr>
<tr>
<td>Business expectation (manufacturing orders)</td>
<td>Expectation of total new orders received</td>
</tr>
<tr>
<td>Wholesale sales</td>
<td>Wholesale sales volume</td>
</tr>
<tr>
<td>Capital expenditure intentions</td>
<td>Investment intentions on buildings in the manufacturing sector</td>
</tr>
<tr>
<td>Total investment</td>
<td>Total investment in the manufacturing sector</td>
</tr>
<tr>
<td>Money supply</td>
<td>Money supply (M2)</td>
</tr>
<tr>
<td>National savings</td>
<td>Money supply (Savings &amp; other deposits)</td>
</tr>
<tr>
<td>Interest rate</td>
<td>Prime lending rate (per S$1000)</td>
</tr>
<tr>
<td>Unemployment</td>
<td>Unemployment rate</td>
</tr>
<tr>
<td>GDP deflators</td>
<td>GDP deflators (base yr 1990=100)</td>
</tr>
</tbody>
</table>
6.4.3 Demand for commercial building construction

In the study, commercial building construction demand is represented by the national level statistical series, "Gross floor area of commercial developments commenced". The theoretical indicators and their equivalent national level statistical series are listed in Table 6.4.

Table 6.4 National level statistical series for indicators of commercial construction demand

<table>
<thead>
<tr>
<th>Theoretical Indicators</th>
<th>National Level Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP</td>
<td>GDP at 1990 market prices</td>
</tr>
<tr>
<td>Unemployment</td>
<td>Unemployment rate</td>
</tr>
<tr>
<td>Cyclical or leading indicators</td>
<td>Composite leading index (base yr 1985=100)</td>
</tr>
<tr>
<td>GDP deflators</td>
<td>GDP deflators (base yr 1990=100)</td>
</tr>
<tr>
<td>Commercial land values</td>
<td>URA’s sale of sites for commercial development</td>
</tr>
<tr>
<td>Business conditions</td>
<td>Business expectations in the commercial sector</td>
</tr>
<tr>
<td>Retail sales</td>
<td>Retail sales volume index (base yr 1991=100)</td>
</tr>
<tr>
<td>Property rental values</td>
<td>Rental values (commercial properties)</td>
</tr>
<tr>
<td>Property price index</td>
<td>Commercial property price index (base yr 1990=100)</td>
</tr>
<tr>
<td>Tourist arrivals</td>
<td>Total visitor arrivals (air, sea &amp; land)</td>
</tr>
<tr>
<td>Money supply</td>
<td>Money supply (M2)</td>
</tr>
<tr>
<td>National savings</td>
<td>Money supply (Savings &amp; other deposits)</td>
</tr>
<tr>
<td>Interest rate</td>
<td>Prime lending rate (per S$1000)</td>
</tr>
<tr>
<td>Planning approval issued</td>
<td>Gross floor area of commercial developments granted planning approval</td>
</tr>
<tr>
<td>Foreign investment</td>
<td>Foreign investment in Singapore (commerce)</td>
</tr>
<tr>
<td>Population</td>
<td>Size of population</td>
</tr>
<tr>
<td>GDP per head</td>
<td>Per capita GDP</td>
</tr>
<tr>
<td>Productivity</td>
<td>Productivity growth</td>
</tr>
<tr>
<td>Employment</td>
<td>Employment in the commercial sector</td>
</tr>
<tr>
<td>Fixed investments</td>
<td>Total cost of commercial developments completed</td>
</tr>
</tbody>
</table>
6.5 Statistical selection of economic indicators

The variable selection procedures, the Stepwise Selection and the Forward Selection, are applied to the three distinct datasets, each representing a different type of demand for building construction. Different entry and exit levels of significance are also specified for each selection procedure. The results of the statistical selection are given in the following sub-sections.

6.5.1 Demand for residential building construction

Two national level statistical series were considered suitable to represent demand for residential building construction. They are, namely, "Gross floor area of residential developments commenced" and "Gross fixed capital formation for residential buildings". However, the former was chosen on the basis that it better defines and measures construction demand, both theoretically and statistically. In theory, the latter is more commonly used to represent output rather than demand. When a preliminary selection procedure is applied to both series, the former is also found to have a stronger relationship with a greater number of indicators. Instead of using the latter series as the dependent variable, it is more appropriate as an independent variable and is, therefore, added to the list of indicators to be selected.

Although regarded as an important measure of construction demand, "Contractors' new order" or "Value of contracts awarded" is not considered in the study because data for this statistical series are only available from 1986. This is the case for residential, industrial and commercial building construction.

The results of the statistical selection of economic indicators for residential building construction demand are given in Table 6.5.
### Table 6.5 Results of statistical selection for residential construction demand

<table>
<thead>
<tr>
<th>FORWARD</th>
<th>STEPWISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry (0.05)</td>
<td>Building material price index; Building tender price index; Consumer price index; Planning approval issued; Bank lendings (Housing); Population; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); Unemployment.</td>
</tr>
<tr>
<td>R-Sq: 0.93399</td>
<td>R-Sq: 0.93106</td>
</tr>
<tr>
<td>Adjusted R-Sq: 0.92399</td>
<td>Adjusted R-Sq: 0.92407</td>
</tr>
<tr>
<td>Std Error: 116.20363</td>
<td>Std Error: 116.1441</td>
</tr>
<tr>
<td>Entry (0.10)</td>
<td>Building tender price index; Bank lendings (Housing); Population; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); Unemployment.</td>
</tr>
<tr>
<td>Entry (0.10); Exit (0.15)</td>
<td>Building tender price index; Bank lendings (Housing); Population; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); Unemployment.</td>
</tr>
<tr>
<td>R-Sq: 0.93399</td>
<td>R-Sq: 0.93106</td>
</tr>
<tr>
<td>Adjusted R-Sq: 0.92399</td>
<td>Adjusted R-Sq: 0.92407</td>
</tr>
<tr>
<td>Std Error: 116.20363</td>
<td>Std Error: 116.1441</td>
</tr>
<tr>
<td>Entry (0.50)</td>
<td>Building material price index; Building tender price index; Consumer price index; Disposable income; Wages and earnings; Planning approvals issued; Bank lendings (Housing); Money supply; GDP per head; Population; Property price index; Productivity; Real GDP; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); Unemployment.</td>
</tr>
<tr>
<td>Building tender price index; Bank lendings (Housing); Population; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); Unemployment.</td>
<td></td>
</tr>
<tr>
<td>R-Sq: 0.95898</td>
<td>R-Sq: 0.93106</td>
</tr>
<tr>
<td>Adjusted R-Sq: 0.94717</td>
<td>Adjusted R-Sq: 0.92407</td>
</tr>
<tr>
<td>Std Error: 96.88193</td>
<td>Std Error: 116.1441</td>
</tr>
</tbody>
</table>

#### 6.5.2 Demand for industrial building construction

The results of the statistical selection of economic indicators for demand for industrial building construction are tabulated in Table 6.6.
Table 6.6 Results of statistical selection for industrial construction demand

<table>
<thead>
<tr>
<th>Entry (0.05)</th>
<th>Forward</th>
<th>Stepwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate; Export of goods; Export price index; Government rates and fees; Interest rate; Leading indicators; Business expectation (manufacturing orders); Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit labour cost; Wholesale sales.</td>
<td>0.95244</td>
<td>0.93928</td>
</tr>
<tr>
<td>R-Sq: 0.95244</td>
<td>Adjusted R-Sq: 0.93873</td>
<td>Std Error: 29.70269</td>
</tr>
<tr>
<td>Entry (0.10)</td>
<td>Exchange rate; Export of goods; Export price index; Interest rate; Leading indicators; Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit labour cost.</td>
<td>0.93928</td>
</tr>
<tr>
<td>R-Sq: 0.93928</td>
<td>Adjusted R-Sq: 0.92789</td>
<td>Std Error: 32.22281</td>
</tr>
<tr>
<td>Entry (0.50)</td>
<td>Business conditions; GDP deflators; Exchange rate; Export of goods; Export price index; Capital expenditure intentions; Government rates and fees; Interest rate; Leading indicators; Money supply; Business expectation (manufacturing orders); Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit business cost; Unit labour cost; Wholesale sales.</td>
<td>0.95550</td>
</tr>
<tr>
<td>R-Sq: 0.95550</td>
<td>Adjusted R-Sq: 0.94169</td>
<td>Std Error: 28.97560</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entry (0.10); Exit (0.15)</th>
<th>Forward</th>
<th>Stepwise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange rate; Export of goods; Export price index; Capital expenditure intentions; Interest rate; Leading indicators; Money supply; Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit labour cost.</td>
<td>0.95550</td>
<td>0.94404</td>
</tr>
<tr>
<td>R-Sq: 0.95550</td>
<td>Adjusted R-Sq: 0.94404</td>
<td>Std Error: 28.38594</td>
</tr>
<tr>
<td>Entry (0.50)</td>
<td>Business conditions; GDP deflators; Exchange rate; Export of goods; Export price index; Capital expenditure intentions; Government rates and fees; Interest rate; Leading indicators; Money supply; Business expectation (manufacturing orders); Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit business cost; Unit labour cost; Wholesale sales.</td>
<td>0.95940</td>
</tr>
<tr>
<td>R-Sq: 0.95940</td>
<td>Adjusted R-Sq: 0.94286</td>
<td>Std Error: 28.68386</td>
</tr>
</tbody>
</table>
6.5.3 Demand for commercial building construction

Similarly for commercial building construction demand, results of the statistical selection are given in Table 6.7.

Table 6.7 Results of statistical selection for commercial construction demand

<table>
<thead>
<tr>
<th></th>
<th>FORWARD</th>
<th>STEPWISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry (0.05)</td>
<td>Planning approval issued; Commercial land price; Productivity; Unemployment.</td>
<td>Entry (0.05); Exit (0.10) Planning approval issued; Commercial land price; Productivity; Unemployment.</td>
</tr>
<tr>
<td></td>
<td>R-Sq: 0.82496 Adjusted R-Sq: 0.81523</td>
<td>R-Sq: 0.82496 Adjusted R-Sq: 0.81523</td>
</tr>
<tr>
<td>Entry (0.10)</td>
<td>Planning approval issued; Commercial land price; Productivity; Retail sales; National savings; Unemployment.</td>
<td>Entry (0.10); Exit (0.15) Planning approval issued; Commercial land price; Productivity; Retail sales; National savings.</td>
</tr>
<tr>
<td></td>
<td>R-Sq: 0.85722 Adjusted R-Sq: 0.84468</td>
<td>R-Sq: 0.85711 Adjusted R-Sq: 0.84704</td>
</tr>
<tr>
<td>Entry (0.50)</td>
<td>Business conditions Planning approval issued; Property price index; Employment (commercial sector); Foreign investment; Interest rate; Commercial land price; Leading indicators; Money supply; GDP per head; Productivity; Real GDP; Property rental value; Retail sales; National savings; Tourist arrivals; Unemployment.</td>
<td>Exit (0.15) Planning approval issued; Commercial land price; Productivity; Retail sales; National savings.</td>
</tr>
<tr>
<td></td>
<td>R-Sq: 0.90691 Adjusted R-Sq: 0.88009</td>
<td>R-Sq: 0.85711 Adjusted R-Sq: 0.84704</td>
</tr>
</tbody>
</table>

6.6 Summary of statistical selection results

From the results of the statistical selection, it can be observed that for all three types of construction demand, the largest subset of selected indicators is obtained by the Forward Selection method using an entry significance level of 0.50. As explained earlier, the largest subset would provide an
exhaustive list of indicators that has satisfied both economic significance and statistical adequacy. The following lists such indicators for residential, industrial and commercial building construction demand.

a) Indicators selected for residential building construction demand are:

- Building material price index;
- Building tender price index;
- Consumer price index;
- Disposable income;
- Wages and earnings;
- Planning approvals issued;
- Bank lendings (Housing);
- Money supply;
- GDP per head;
- Population;
- Property price index;
- Productivity;
- Real GDP;
- Housing stock (additions);
- National savings;
- Gross fixed capital formation (residential buildings); and
- Unemployment.

b) Indicators selected for industrial building construction demand are:

- Business conditions;
- GDP deflators;
- Exchange rate;
- Export of goods;
- Export price index;
- Capital expenditure intentions;
- Government rates and fees;
- Interest rate;
Leading indicators;
Money supply;
Business expectation (manufacturing orders);
Industrial and manufacturing production;
Population;
Productivity;
Real GDP;
National savings;
Total investment (manufacturing);
Trade balance;
Unemployment;
Unit business cost;
Unit labour cost; and
Wholesale sales.

c) Indicators selected for commercial building construction demand are:

Business conditions
Planning approval issued;
Property price index;
Employment (commercial sector);
Foreign investment;
Interest rate;
Commercial land price;
Leading indicators;
Money supply:
GDP per head;
Productivity;
Real GDP;
Property rental value;
Retail sales;
National savings;
Tourist arrivals; and
Unemployment.
6.7 Discussion of findings

There are two main issues to discuss in relation to the findings of this chapter. Firstly, justifications have to be found for those indicators that have been theoretically identified as influencing factors, but were not selected by the statistical procedure. Secondly, in order to reduce the possibility of overfitting and multicollinearity, a smaller subset of significant indicators need to be identified for modelling purposes. These aspects are dealt with, respectively, in Sections 6.7.1 and 6.7.2.

6.7.1 Justifications for disparity between theoretical identification and statistical selection

It is obvious from the results of the statistical selection that despite the use of a less restrictive variable selection procedure, it did not select all of the theoretical indicators in any case. This is to be expected because the use of significance levels ensures that only those variables that have met the specified selection criteria are included. Now, there is a need to re-examine those theoretical indicators that have not been statistically selected to decide if they should be omitted totally. Otherwise, they can still be included solely on good theoretical grounds.

For residential construction demand, the indicators that have not been statistically selected are "GDP deflators", "Interest rate" and "Household formation". Firstly, GDP deflators are indicators of overall national price changes, covering all sectors namely, consumer, government, investment, and international components. Although they are considered as the broadest and best indicators of economy-wide inflation, they may become too general when related specifically to demand in the residential construction sector. As housing has always been viewed as the single most expensive, hence important, consumer good of an average household, the Consumer Price Index may be a more precise indicator of this type of demand. This may help to explain why the Consumer Price Index, and not the GDP deflators, has been selected as one of the significant variables. Secondly, according to economic theory, interest rate is expected to have a relationship with demand for residential construction since it is the main determinant of the cost of borrowing which affects mortgage loans. However, this departure from theory may be justifiable in the case of Singapore as the public sector has the largest share in the country's residential construction. The ongoing public housing scheme implemented by the government has to date housed 90 per cent of the total population. Demand for government-subsidised housing would not be greatly influenced by the rate of interest because, in any case, the substantial savings in purchasing these low-cost housing would have far compensated for any rise in the cost of borrowing, making interest rate an insignificant issue. Thirdly, household
formation has often been considered, in theory, as a crucial factor that influences demand for housing construction. However, quantitative studies (Tang et al., 1990; and Goh, 1996) have shown the contrary. In this study, the statistical insignificance of household formation may be attributable to the use of the national level statistical series "Number of marriages registered". Again, this may be a unique case for Singapore as young married couples are encouraged to live with their parents to form a multi-generation family unit. Hence, for the purpose of studying housing construction demand, the number of marriages registered may not accurately depict household formation in Singapore. However, no alternative series was available to represent this indicator.

The only indicator that was found to be insignificant for industrial construction demand is "GDP per head". In general, this indicator reflects national output per person, which acts as a good guide to a country's general living standards. Although generally useful, it may bear little direct relations with the industrial sector. On the other hand, it should have more direct and immediate influence on the residential and commercial sectors since the general living standards of a nation usually imply the population's spending power on items such as housing and retail goods. This line of reasoning is supported by GDP per head having been found to be a significant indicator of both residential and commercial construction demand.

In the case of demand for commercial building construction, three theoretical indicators were found to be statistically insignificant and they are, "GDP deflators", "Fixed investments" and "Population". Firstly, GDP deflators may, again, be too wide or general in terms of measuring the level of inflation as it covers many other sectors besides the consumer. Since the commercial sector deals mainly with the retail trade, a narrower indicator of the level of price change, such as the Consumer Price Index, may have more direct effects on this consumer-based sector and, hence, the level of construction demand. Secondly, the indicator "Fixed investments" has been represented by the national level statistics "Total cost of commercial developments", which may have measured and reflected only the cost of construction. In land-scarce Singapore, the cost of construction constitutes only a small proportion of total development cost which also includes the cost of land. Hence, decisions to invest in commercial developments are chiefly influenced by the prevailing price of commercial land. This point is substantiated by "Commercial land price" being one of the significant indicators. Thirdly, although population size was not found to be significant by itself, this does not mean that it has no influence on the commercial sector at all. This indicator is often used as a yardstick for minimum GDP growth because of its use in GDP per head. When interpreting GDP per head, real GDP must grow faster than the size of population if living standards are to improve. As explained earlier, improved living standards increases spending power, giving rise to higher demand for retail goods.
and, therefore, buildings to contain such increased activities. From this, it may be suggested that although the size of population does not relate directly to demand for commercial buildings, it does have its influence through GDP per head.

Justification can be found for all the unselected indicators, indicating that the statistical approach has successfully achieved its objective of sieving out the less suitable variables. However, there are some general shortcomings of such statistical procedures which need to be addressed here. Firstly, it has been emphasized that automated variable selection procedures are not the panacea many users have been led to expect: prior information about the model can be useful to the selection of a more suitable set of modelling variables (Freund and Littell, 1986). From a statistical viewpoint, Draper and Smith (1981) attributed the shortcomings of statistical procedures to the lack of knowledge of the magnitude of the true random variance of the observations for any single well-defined problem, making the choice of a best regression equation impossible. Hence, it becomes necessary to rely on personal judgement in any of the selection methods used. Secondly, a major limitation of any statistical analysis is that the outcome is largely dependent on the quality and quantity of data used. For quality, this is particularly true when dealing with archival data, as opposed to empirical, since there is less control over the recording and updating of data; the competence of the personnel maintaining the data banks has to be relied upon. With regard to quantity, those indicators that were found to be insignificant may perhaps become significant when more data become available.

6.7.2 Choice of modelling variables for residential construction demand

Chapter 10 of this thesis embarks on the modelling of residential construction demand in Singapore and the findings of this chapter would provide the case study with some useful modelling variables. The choice of a suitable set of modelling variables is discussed here.

Owing to the variable nature of statistical selection methods, where different methods do not give the same results, there is a need to choose one that will suit a specific purpose. For model estimation, a smaller number of variables is usually preferred in order to lessen the effects of overfitting and multicollinearity. Hence, the largest subset of indicators selected by the Forward Selection procedure based on a significance level of 0.50 cannot serve this purpose. Nevertheless, there must also be a sufficient number of modelling variables to allow a satisfactory level of coefficient of determination, or R-square, to be achieved, thus serving as a convenient measure of success of the regression equation in explaining the variation in the data (Draper and Smith, 1981). But, there is a drawback in the use of R-square which has resulted in the Adjusted R-square being
preferred as a descriptive measure of the strength of association between the dependent variable and the independent variables. In essence, if any independent variable, however irrelevant, is added to a regression model, the sum of squared errors would almost inevitably fall, at least marginally. Consequently, the addition of an irrelevant independent variable to a regression model would produce at least a modest increase in the R-square. It is undesirable to have this misleading effect on a measure often taken as an indication of the success of a regression procedure. In the case of the Adjusted R-square, the corrected coefficient of determination ensures that the addition of a variable to a regression model does not necessarily lead to an increase in the R-square as the associated degrees of freedom would have been used for its adjustments.

Between the two selection procedures implemented in the study, the Stepwise Selection is a more stringent method as it ensures that the subset of variables selected at every stage is optimum. In the case of residential construction demand, the Stepwise procedure has selected seven indicators for both specified significance levels. They are:

- Building tender price index;
- Bank lending (Housing);
- Population;
- Housing stock (additions);
- National savings;
- Gross fixed capital formation (residential buildings); and
- Unemployment.

The Forward Selection procedure has generally selected a larger number of significant indicators. Both significance levels (0.05 and 0.10), specified in this method, selected the following 10 indicators:

- Building material price index;
- Building tender price index;
- Consumer price index;
- Planning approval issued;
- Bank lending (Housing);
- Population;
- Housing stock (additions);
- National savings;
Gross fixed capital formation (residential buildings); and
- Unemployment.

The choice between these two subsets of indicators would have to depend on the descriptive statistics obtained. As expected, the Forward Selection procedure attained a higher R-square (0.93399) than the Stepwise procedure (0.93106) owing to its larger set of indicators. However, on comparing their Adjusted R-squares, the Stepwise procedure is able to achieve a higher adjusted value (0.92407) than the Forward method (0.92399). Its standard error (116.14) is also marginally smaller than that of the Forward method (116.20). Based on these two factors, the subset of indicators selected by the Stepwise procedure is chosen to be the modelling variables for the case-study of Singapore's residential construction demand.

6.8 Chapter summary

A statistical selection of economic indicators that are significantly related to demand for different types of building construction in Singapore has been carried out in this chapter. The indicators involved in the statistical selection process had originally been theoretically identified. The eventual list of indicators selected would have met both economic significance and statistical adequacy criteria. The data collection process has been fully described in Section 6.2 with regard to the source of data, and the sample size and frequency. In this study, secondary data sources were relied upon as it necessitated the use of massive amounts of published economic time-series data. The statistical system of Singapore was briefly accounted, covering the four phases of evolution and a highlight of issues relating to the decentralised system, integrity of official statistics, maximisation of returns and public concerns. Major statistical activities in the public sector have also been described in terms of the responsibilities undertaken by the Department of Statistics, and the different government ministries and statutory boards. Together, they supply the policy makers and the general public with the required national statistical information.

In Section 6.3, the methodology adopted for the statistical selection process was elaborated. The first stage involved data transformations such as deflating current price data to constant prices, disaggregating annual time series to quarterly figures, and applying moving averages to eliminate seasonality and randomness from the data series. Once the data has been transformed, the second stage entailed the use of variable selection procedures namely, the Stepwise Selection and the Forward Selection, to obtain a subset of indicators that would produce the maximum coefficient of
determination (or R-square). The steps involved in these two procedures were discussed in detail, including the choice of different levels of statistical significance.

In order to associate theory with statistics, Section 6.4 carried out a re-classification of the theoretical indicators according to national level statistics. It provided three separate lists of theoretical and statistical classifications of economic indicators for residential, industrial and commercial building construction demand. In essence, for each theoretical indicator, an equivalent national level statistics would be identified. These statistical time-series data would in turn be used in the selection process.

The results of the statistical selection process for residential, industrial and commercial building construction demand were summarised in Section 6.5, under Tables 6.5, 6.6 and 6.7, respectively. They showed the results of both the Forward and Stepwise Selection methods, applying different levels of significance. Descriptive statistics such as the R-square, the Adjusted R-square and the standard error were also provided for each set of results. This is to further aid the choice of the best subset of indicators that would be used in the modelling process.

For the purpose of selecting a subset of indicators that would provide consensus between theory and statistics, the results of the Forward Selection procedure applying the lowest entry level of significance (0.50) were used to represent the outcome of the statistical selection process. This was fully explained in Section 6.6. In summary, the economic indicators that met both economic significance and statistical adequacy for residential building construction demand were: Building material price index; Building tender price index; Consumer price index; Disposable income; Wages and earnings; Planning approvals issued; Bank lendings (housing); Money supply; GDP per head; Population; Property price index; Productivity; Real GDP; Housing stock (additions); National savings; Gross fixed capital formation (residential buildings); and Unemployment. For industrial building construction demand, the selected indicators were: Business conditions; GDP deflators; Exchange rate; Export of goods; Export price index; Capital expenditure intentions; Government rates and fees; Interest rate; Leading indicators; Money supply; Business expectation (manufacturing orders); Industrial and manufacturing production; Population; Productivity; Real GDP; National savings; Total investment (manufacturing); Trade balance; Unemployment; Unit business cost; Unit labour cost; and Wholesale sales. Those selected for commercial building construction demand were: Business conditions; Planning approval issued; Property price index; Employment (commercial sector); Foreign investment; Interest rate; Commercial land price; Leading indicators; Money supply; GDP per head; Productivity; Real GDP; Property rental value; Retail sales; National savings; Tourist arrivals; and Unemployment.
The chapter concluded with a discussion of findings in Section 6.7. The study was able to provide justifications for indicators that were not selected by the statistical procedure. This indicated that the statistical selection had successfully sieved out the less significant factors. However, a few limitations of statistical approaches were also highlighted, acknowledging the fact that the success of any statistical study also depends on human judgement, and the quality and quantity of data used.

The final discussion topic dealt with the choice of a smaller subset of variables for residential construction demand. This subset of indicators will be used in Chapter 10 to model demand for residential building construction in Singapore. In order to lessen the effects of overfitting and multicollinearity, a smaller set of indicators is generally preferred. A choice had to be made between the two subsets derived from the Stepwise and Forward Selection procedures. Useful descriptive statistics such as the R-square, the Adjusted R-square and the standard error were relied upon in making the choice. Based on a higher Adjusted R-square and a smaller standard error, indicators selected by the Stepwise procedure were considered more suitable.
CHAPTER 7

A PROPOSED SYSTEMATIC APPROACH TO IDENTIFYING AND SELECTING ECONOMIC INDICATORS FOR CONSTRUCTION DEMAND MODELLING

7.1 Introduction

This chapter marks the conclusion of the first part of the study. To reiterate the premise upon which this part is based, it is that there has been insufficient examination of all possible economic indicators for use in modelling construction demand, and it may be attributed to the absence of a systematic approach to the identification and selection of indicators which satisfy the economic significance and statistical adequacy criteria. Following the activities involved in Chapters 5 and 6, which culminated in the selection of a set of suitable variables for modelling construction demand, the objective of this chapter is to integrate these different stages into a systematic approach. It proposes to serve as a guide for future research in this area.

Firstly, the various steps of theoretical identification of economic indicators are summarised in Section 7.2. This is followed by a brief discussion of the steps involved in the statistical selection in Section 7.3. Together, they ensure that the final set of indicators used to model demand for construction would have met both economic significance and statistical adequacy.

Secondly, a proposal is made to integrate the stages of identification and selection into a systematic approach in Section 7.4. A schematic representation is provided to better illustrate this stage-by-stage approach.

Finally, a rigorous discussion of the proposed approach is carried out in Section 7.5. Implications for future studies in construction demand modelling are given. Problems anticipated in the use of this approach are also highlighted, followed by some recommended solutions.

7.2 The stage of theoretical identification of economic indicators

In order to build good predictive models, it is important to consider all possible factors which can be used as significant modelling variables. Past studies of construction demand modelling have
generally adopted a less rigorous approach. It usually entails a random selection of some factors which, based on judgement and economic theory, have an influence on demand. The shortcoming of this kind of approach is that there is an element of subjectivity in the choice of the initial set of indicators. Besides, the number of factors considered is often small, since it is always easier to work with lesser variables. This number would be further reduced once a statistical variable selection procedure is imposed (Tang et al., 1990; and Akintoye and Skitmore, 1994). It is important to realise the grave consequences of omitting relevant variables in a model. Its parameter estimates would be bias and wrong, and its standard error would be high. These factors would directly affect the model's ability to predict. In order to avoid such problems, the study advocates the examination of all possible economic indicators that relate to construction demand. In the first stage, the theoretical identification of indicators is carried out in three distinct steps.

The first step entails a detailed examination of the characteristics and determinants of the type of demand concerned. In the case of residential construction demand, the general characteristics are that demand for new housing construction is subject to extreme cyclical fluctuations, and housing is typically the most expensive item bought by a single household which is financed mainly by mortgage credit. The findings of this initial step will greatly facilitate the activities in the next step.

In the second step, a thorough literature search is carried out to obtain a list of economic and social factors that relate to the type of demand concerned. On the one hand, this rigorous process helps to generate theoretical justifications for the identified factors, ensuring that every factor satisfies the economic significance criterion. On the other hand, it helps to eliminate unrelated or insignificant factors from further consideration. Essentially, a good understanding of the characteristics and determinants of the type of demand clearly assists in narrowing down the range of factors to be considered. In the case of residential construction demand, economic and social factors related to economic cycles, consumer expenditure and monetary policies need to be focused upon.

The final step involves the selection of one or more economic indicators that represent each economic or social factor that has been identified in the second step. It serves as a crucial step to expand on these factors in order to be more precise and thorough in their definition. For example, mortgage credit availability can be represented by economic indicators such as, money supply, national savings and bank lendings. This has effectively enlarged the number of related indicators to be considered, increasing the likelihood of selecting better modelling variables.
7.3 The stage of statistical selection of economic indicators

The objective of the statistical selection stage is to establish the statistical adequacy of the indicators. Incidentally, it also helps to reduce the long list of indicators to a final short list which is more parsimonious for modelling purposes. Past studies of construction demand modelling (Tang, et al., 1990; Akintoye and Skitmore, 1994; and Goh, 1996) have shown that the adoption of a variable selection procedure is a feasible approach to identifying statistically significant determinants of demand. It removes variables which do not meet the level of significance specified in the selection procedure from further consideration and, at the same time, provides statistical justification for those that are included. Killingsworth (1990), on the other hand, relied on visual identification of correlated determinants based on a graphical analysis of the dependent and independent variables. Although more straightforward, visual approaches are usually not recommended as it lacks objectivity and justification (Makridakis et al., 1983). This study has used the statistical approach of selecting variables and the various steps involved are discussed here.

Before the actual selection procedure can be implemented, it is often preceded by the stage of data collection and preprocessing. The first step of this stage requires a re-classification of the economic indicators by identifying their equivalent national level statistics so as to aid the collection of data from published sources. This is necessary because of the different terminology used in theory and statistics in describing economic indicators. Once this is completed, the next step involves the collection of published time-series data from statistical yearbooks and economic reports. The raw data has to be preprocessed or modified before it can be statistically analysed. It is common for time-series data to undergo three steps of transformation namely, deflation, disaggregation and smoothing. The transformed data is now ready for the variable selection process.

During this stage, a few crucial decisions have to be made concerning the choice of the variable selection methods and the appropriate levels of significance to be used. This is where the expert judgement of the modeller is required. Some methods are more restrictive than others, resulting in lesser variables selected. Hence, the modeller must be clear of his initial objectives. A less restrictive method is recommended for obtaining an exhaustive list of theoretically significant and statistically adequate indicators, while a more restrictive one is required to obtain a shorter list of regressors that is suitable for modelling purposes. In addition, the use of appropriate levels of significance is important in ensuring the effectiveness of the selection methods. Therefore, decisions on the choice of selection methods and levels of significance have to be made concurrently. Once
a list of statistically significant indicators has been obtained, the next step involves examining those indicators that have not been selected. This is necessary because such indicators may still be used as additional modelling variables based solely on their economic significance. The fact that they have been eliminated in the statistical selection process does not immediately make them unsuitable. Strong theoretical grounds can often precede any statistical basis. In short, the brute force of automated variables selection procedures is no substitute for knowledge of the data and subject matter (Freund and Littell, 1986). However, if justification can be established for their insignificance, then they would be deemed as unsuitable modelling variables at this stage.

It is important to highlight the various outcomes of the statistical selection stage. These are considered under the final stage and, that is, usage. As already mentioned, the statistical selection process can be used to produce different sets of indicators, depending on the initial objectives of the modeller. Firstly, it can provide an exhaustive list of indicators which satisfies both economic significance and statistical adequacy criteria. Secondly, it can provide a short list of indicators which is more suitable for modelling purposes. Lastly, it can also produce a list of theoretically significant indicators which may serve as additional modelling variables.

7.4 A proposed stage-by-stage approach

The steps involved in the theoretical identification and statistical selection have been outlined above. The following sub-sections attempt to summarise the various steps and stages of the proposed approach.

7.4.1 Introduction

The purpose of proposing a stage-by-stage approach is to obtain a set of organised procedures (or steps) that, when executed, provides a list of economic indicators, which meets both economic significance and statistical adequacy criteria, to be used as variables for modelling construction demand. The need for a systematic method arises because one has to involve all related economic and social factors. It is only by adopting a structured approach that it can be ensured that every factor has been considered; a thorough process which compels the understanding of the intricate relationship between the general economy and the construction industry. In essence, the approach seeks to reduce the extent of uncertainty and subjectivity in an area where already "attempts to
estimate demand for construction are fraught with difficulties, owing to the characteristics of construction items" (Ofori, 1990:110).

7.4.2 A schematic representation

A schematic representation of the proposed stage-by-stage approach is used to summarise the various steps and stages involved. Figure 7.1 depicts the four-stage approach and illustrates the progression of the different steps in each stage. The proposed approach can be outlined in four distinct stages.

Stage One: Theoretical identification

a) Examine characteristics and determinants of demand for construction;
b) Identify influencing economic and social factors;
c) Check their conformity with economic theory; and
d) Select economic indicators that represent each factor.

Stage Two: Data collection and pre-processing

a) Statistical re-classification of economic indicators;
b) Data collection from published sources; and
c) Apply data transformations such as, deflation, disaggregation and smoothing.

Stage Three: Statistical selection

a) Choose variable selection methods and appropriate levels of significance;
b) Apply chosen selection procedures;
c) Examine results of statistical selection; and
d) Attempt to justify unselected indicators.

Stage Four: Usage

a) Use unselected indicators whose statistical insignificance cannot be justified as additional modelling variables;
b) Use variables that have been selected by the more restrictive procedure to compile an exhaustive list of indicators that has met the economic significance and statistical adequacy criteria; and
c) Use variables that have been selected by the less restrictive procedure to model demand for construction.

7.5 Discussion of proposed approach

In any proposed approach, there are bound to be benefits and shortcomings. These tend to have direct implications for the subject area concerned, in this case, construction demand modelling. It is, therefore, important to ensure that the number of derived benefits exceeds the number of derived problems. However, recognising potential problems does play a vital part in generating ways of improving current practices. In this way, indirect benefits can still be gained if appropriate measures are taken.

Implications of the proposed approach are examined first, followed by a discussion of the anticipated problems. Recommendations of ways of resolving these problems are also given, acting as useful guidelines for future research in construction demand modelling.

7.5.1 Implications for construction demand modelling

With the introduction of the stage-by-stage approach, there are several implications for future works in construction demand modelling. Before discussing these implications, it is important to highlight the main objectives of construction demand modelling, and they are:

1) to discover the factors that influence demand for construction by examining its characteristics and determinants;
2) to build an explanatory model which reveals the true relationship between these influencing factors and demand; and
3) to use the derived model to predict future values of demand for construction.

The first implication of the use of the proposed approach is related to the first objective. The theoretical identification stage requires detailed examination of the characteristics and determinants
Figure 7.1 Flowchart showing stages of identification, preprocessing, selection and usage
Figure 7.1 Flowchart showing stages of identification, preprocessing, selection and usage (Cont'd)
of demand for construction in order to identify potential influencing factors. The idea is to consider all possible factors at an early stage, before eliminating those that do not conform to economic theory in the next step. It implies that a thorough understanding of the nature of demand for construction and its associated economic and social factors is crucial. Hence, a good comprehension of the theory of construction economics is required in order to undertake the stage of theoretical identification effectively. There is a direct implication for modellers to be proficient in the statistical aspects of modelling, as well as, knowledgeable of economic theory.

The second implication is that modellers would not be able to pre-determine the number of variables to be used, which has been the case in past studies (Tang et al., 1990; and Akintoye and Skitmore, 1994). Without this restriction, it means that more potential indicators can be identified. This is in support of the second objective of demand modelling which is to build more realistic explanatory models. On a broader perspective, it also helps to promote an in-depth understanding of the intricate relationship between the general economy and the construction industry.

Following the second implication, less subjectivity involved in the theoretical identification of indicators would imply the building of better predictive models. A thorough examination of all possible influencing factors increases the likelihood of identifying more significant modelling variables. Hence, the third implication is that demand models with higher forecasting abilities can be expected as a result of using more significant modelling variables. This, in effect, fulfils the third objective of construction demand modelling.

Increased complexity in future modelling tasks is the final implication. Apparently, the consideration of more influencing factors increases the number of modelling variables. Hence, modellers must be prepared for greater complexities in the modelling process. As complex models do not necessarily mean better models, a general observation made by some writers (Jenkins, 1979; and Makridakis et al., 1982), expert judgement needs to be applied in order to keep a balance between complexity and efficiency. Better knowledge of the data and subject matter would help to ensure that a parsimonious set of variables is used. The proposed approach allows for judgemental input in Stage Three where the degree of complexity can be regulated by the type of variable selection method and the level of significance chosen. Modellers would have to be familiar with the use of alternative selection methods and the relevance of different levels of significance in order to play a more active role in the future.
7.5.2 Problems anticipated

From the discussion of the implications of the proposed stage-by-stage approach, several problems can be anticipated. It is necessary to examine these potential problems and recommend courses of action to resolve them.

The first problem relates to the availability of data. As the approach advocates a thorough examination of all possible factors of construction demand, it raises the expectations of the availability, accessibility and quality of statistical data. Without a broad base of economic and social statistics, the statistical significance of suitable indicators cannot be tested owing to the unavailability of data. To help resolve this problem, the resourcefulness of the researcher is important. Often, many do not go beyond extracting information from national data sources. There are also external research organisations compiling vital national statistics of countries worldwide, with the aim of providing potential foreign investors an independent account of a country's past and present economic position. International institutions such as, Organisation for Economic Co-operation and Development (OECD), International Monetary Fund (IMF) and the United Nations, also compile and publish information on national economic indicators of many countries. In short, it is recommended that for studies relying on data from secondary sources, a detailed search of all available published sources is warranted. It increases the likelihood of obtaining more data which may be crucial to the expansion of the scope of the research.

Following the difficulty in data collection, the second problem is associated with the time factor. It is apparent that the approach will be more time consuming as more factors have to be considered and more data to be collected. However, if a more accurate and realistic model is compensated for the longer time spent, the trade-off may prove to be worthwhile. Nevertheless, it is recommended that initial studies adopting the approach should carry out comparative studies to justify the proposition that the consideration of more associated indicators indeed produces better forecasting models. Otherwise, the mere fact that the approach eliminates subjectivity in the choice of suitable modelling variables may alone be a sufficient basis for its adoption.

In a statistical sense, the use of more modelling variables increases the chance of encountering problems such as, overfitting and multicollinearity. Therefore, it is recommended that extra care is given during the theoretical identification stage. Indicators which measure similar economic or social phenomena should not be used concurrently as it would inevitably introduce a high degree of
multiple correlation among them, giving rise to problems of multicollinearity. Over-enthusiasm during the identification stage causes too many factors to be considered. As a result, time is wasted on data collection and the risk of overfitting the model increases. Hence, ample knowledgeable of the theory of construction economics is required in order to be more selective at this early stage. Better modelling skills are also necessary to detect and resolve the potential problem of multicollinearity at a later stage.

It is clear that the proposed approach imposes on the modeller the requirement to familiarise himself with alternative variable selection methods. Without acquiring better technical skills, the chances of deriving spurious and unparsimonious models are high. More advanced methods, such as principal component regression and biased estimation, may also be useful. They can serve as viable alternatives to variable selection methods especially if the primary objective is to study the structure of the regression relationship and not only to predict values of future demand.

7.6 Chapter summary

This chapter has proposed a stage-by-stage approach to the theoretical identification and statistical selection of economic indicators for construction demand modelling. The systematic approach has been rigorously discussed which included a detailed description of each stage, a schematic representation, implications of its use and the potential problems.

In Section 7.2, the steps involved in the first stage of theoretical identification were elaborated. The first step entails a detailed examination of the characteristics and determinants of the type of demand for construction concerned. This is followed by a thorough literature search to obtain a list of economic and social factors that has been associated with this type of demand. The final step involves the selection of one or more economic indicators that represent each of these factors.

The discussion in Section 7.3 dealt chiefly with the statistical selection stage. It began with a description of the steps involved in the data collection and preprocessing stage. It comprised the reclassification of economic indicators using statistical terminology, the collection of economic time-series data from published sources and data transformation to remove the unwanted statistical properties. The objective is to collect and prepare the data for the statistical selection stage. In this stage, decisions have to be made with regard to the usage of the selected indicators, and the types
of variable selection methods and levels of significance to be applied. Generally, by determining the usage of the indicators, the choice of appropriate selection methods and levels of significance could be implied. A less restrictive method would produce an exhaustive list of indicators which satisfies both economic significance and statistical adequacy. A more restrictive method would derive a shorter list of indicators that is suitable for modelling purposes. A list of additional modelling variables can also be obtained.

In Section 7.4, a schematic representation of the four-stage approach was given in Figure 7.1. The section also explained the need for a systematic approach and outlined the different steps involved in each stage.

Finally, the benefits and shortcomings of the proposed approach were discussed in Section 7.5. In particular, four implications of the use of the approach were highlighted. They relate to the main objectives of construction demand modelling. The first implication was that the approach would encourage a more thorough examination of the different economic and social factors that influence construction demand, especially with a better understanding of the characteristics and determinants of demand. It also meant that modellers would have to be more knowledgeable of economic theory in order to fulfil their future role. The second implication was that the approach would allow for more potential indicators to be considered, increasing the likelihood of developing better explanatory models which can reveal more meaningful relationships between the influencing factors and demand for construction. With less subjectivity in the choice of suitable indicators, the third implication was that better predictive models should emerge as a result of using more relevant variables after taking into consideration all possible ones. Increased complexity of future modelling tasks was the final implication. This is the result of using more modelling variables. It was emphasised that care has to be taken to keep a balance between complexity and efficiency. In this respect, the choice of appropriate variable selection methods and levels of significance plays an important part in regulating the complexity of the modelling process. Several problems were also anticipated and they are: non-availability of data, more time-consuming, more prone to problems such as multicollinearity and overfitting, and a higher chance of deriving spurious models owing to a lack of understanding of different statistical selection methods. Recommendation of ways of resolving each problem was given.
CHAPTER 8

THE REGRESSION APPROACH TO FORECASTING: THEORY AND APPLICATIONS

8.1 Introduction

This chapter provides a theoretical background of the regression approach and reviews applications of such methods to model and forecast demand for construction.

The chapter begins by discussing the general need to forecast in Section 8.2. The discussion applies to all levels of the economy, that is, the government, industries and firms.

The theory of quantitative forecasting methods is provided in Section 8.3. There are two broad categories of quantitative forecasting methods namely, Time Series and Causal. The main characteristics of each method is briefly discussed.

Focusing on the Causal method, Section 8.4 elaborates on the key aspects of building explanatory models using regression analysis. Theoretical issues of the regression approach are discussed, covering linear and non-linear methods.

In Section 8.5, several construction demand modelling and forecasting applications are described. The forecasting methods employed are mainly causal, such as the multiple linear and log-linear regression, and a combination of the leading indicators and the multiple regression methods.

Finally, a critique of the prevailing forecasting methods used to model and predict construction demand is provided in Section 8.6.

8.2 The general need to forecast

Basically, forecasts are required for two main reasons. First, the future is uncertain and the full impact of many decisions taken now is not felt until later. Second, accurate predictions of the future improve the efficiency of the decision-making process. Most decisions are made with an intention
of influencing the outcome in the future. A firm builds a factory to meet expected future demand for its products; a working individual decides to save part of his income to make provision for retirement; a stock market investor buys some shares now in the hope of receiving a worthwhile return in dividends or capital gains in the future; and a banker buys foreign currency on the forward market to reduce risks of losses from movements in exchange rates. All these activities require some idea or forecast of the future behaviour of key environmental variables so that an assessment can be made of what will happen if nothing is done now, and what is likely to happen if certain steps are taken.

Business executives and government policy-makers are constantly faced with uncertainty in the economic environment. The perception of such uncertainty has been increasing and has necessitated a more thorough and systematic consideration of the future. Macroeconomic forecasts are essentially needed by all levels of the economy: the government, industries and firms. Governments use forecasts for macroeconomic policy-making. The annual national budget requires estimates of future revenues and future expenditures. Investment in buildings and infrastructures for the country demands sound assessment of future costs and benefits. Each industry in the economy will also have to rely on macroeconomic forecasts to set out their immediate and long-term goals. For example, the construction industry will require economic forecasts such as future business conditions, future levels of public expenditure, national income, population growth and labour force in order to determine its future levels of output, price, manpower requirements and mechanisation. At the enterprise level, all firms are affected by three areas of activity: the macroeconomy; their industry; and the firm itself. Usually, it is only the last of these that the firm can control. Therefore, firms need to have forecasts of the economy and its industry in order to be well-informed about the external environment.

8.3 Theory of quantitative forecasting methods

The importance of forecasting has, without a doubt, grown tremendously during the last thirty years. The interest shown towards forecasting has come from both the academic world and from practitioners. Academics have contributed to a proliferation of forecasting methods and two major groups of quantitative methods are discussed here.

Quantitative forecasting methods vary greatly in sophistication from subjective to formal statistical
methods. These techniques involve the analysis of historical data in an attempt to predict future values of a variable of interest. Lawrence (1983) cited several advantages of using quantitative methods over qualitative ones, and they are:

a) improved accuracy;
b) reduced cost of generating forecasts;
c) greater speed in generating forecasts;
d) assistance to the forecaster in processing past historical data; and
e) improved forecast consistency.

Traditionally, quantitative forecasting methods have been grouped under two distinct types: time-series methods and causal methods. These methods are briefly described below.

Time-series forecasting methods rely on two important factors, the data series to be forecast and the period of time to be used. A time-series model always assumes that some pattern or combination of patterns is recurring over time. By identifying and extrapolating that pattern, forecasts for subsequent time periods can be developed. The method also assumes explicitly that the underlying pattern can be identified solely on the basis of historical data from that series. In essence, time-series forecasting treats the system as a black box and makes no attempt to discover the factors affecting its behaviour. As shown in Figure 8.1, the system, which can be the national economy, a company's sales or a household, is simply regarded as an unknown generating process. The distinguishing feature of a time-series model, as opposed to a causal model, is that a behavioural relationship between the inputs and output of the system is not formulated or discovered (Harvey, 1993). The movements in the output are explained solely in terms of its own past, or by its position in relation to time. Forecasts are then made by extrapolation.

In contrast, causal forecasting methods rely on the cause and effect relationship derived between the output of the system and the corresponding inputs to predict future values of the output. For such methods, any change in the inputs will affect the output of the system in a predictable way, assuming the cause and effect relationship is constant. Figure 8.2 illustrates this cause and effect relationship between the inputs and output of the system. When causal or explanatory models are used in forecasting they can be qualitative, indicating the direction in which a variable is likely to change, or quantitative, predicting the size of movement in the variable of interest. The real strength of a causal model as a forecasting method is that it allows the impact of various alternative inputs to be
System Inputs Generating Output

Figure 8.1 Time-Series Relationship

System Inputs Cause and effect Output

Figure 8.2 Explanatory or Causal Relationship
evaluated. However, the difficulty of these methods is that they require information on several variables in addition to the variable that is being forecast. Hence, explanatory models take longer to develop since several factors are involved and they are more sensitive to changes in the underlying relationships. Furthermore, they require an estimation of future values of the input factors before the output variable can be predicted.

Causal models are most popular in economic and business forecasting where the effects of alternative policies can be appraised. Econometric models are often developed by economists and politicians, adopting advanced causal forecasting methods, to obtain macroeconomic forecasts.

8.4 The Regression Approach

Regression techniques are most commonly applied to develop causal models. They range from simple linear or multiple regression to complex econometrics. In essence, regression techniques are concerned with modelling the relationships among variables. They quantify how a response (or dependent) variable is related to a set of explanatory (or independent) variables. They also rely on the relationship established between the dependent variable and the independent variables to predict future values of the dependent variable. The different methods of carrying out regression analyses are discussed below.

8.4.1 The Classical Linear Regression

The classical linear regression model states that the dependent variable is composed of a mean, which depends in a continuous manner on the independent variables and the random error (Johnson and Wichern, 1992). Effectively speaking, this random error accounts for measurement error and the effects of other variables not explicitly considered in the model. The values of the explanatory variables recorded from the experiment or set by the investigator are treated as fixed. The error, and hence the response, is viewed as a random variable whose behaviour is characterised by a set of distributional assumptions.

Specifically, the linear regression model with a single response takes the form:
\[ y = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k + e \]

where, 
- \( y \) is the single response, or dependent, variable;
- \( x \) is the explanatory, or independent, variable;
- \( \alpha \) is the constant term;
- \( \beta \) is the parameter, or coefficient, estimate of the explanatory variable; and
- \( e \) is the random error term.

The term linear refers to the fact that the mean is a linear function of the unknown parameters, \( \alpha, \beta_1, \ldots, \beta_k \). In order to estimate these regression parameters, a mathematical procedure known as the Ordinary Least Squares (OLS) is used. The procedure is to minimise the sum of the squared vertical deviations between the actual sample values of the dependent variable, \( y \), and the estimated values of \( y \). The objective is to obtain parameter estimates of which the resulting statistical relation provides the best possible fit to the data. The parameter estimates that minimises the sum of the squared deviations can be mathematically expressed as:

\[
S(\beta) = \sum_{i=1}^{n} (y_i - f(x_i; \beta))^2
\]

and are called the least squares estimates of \( \beta \).

In simple linear regression models, the value of the dependent variable is influenced by only a single independent variable, while for multiple linear regression models, there are multiple influences on the dependent variable, using more than one independent variable.

8.4.2 Regression applying linearizing transformations

Generally, the assumption of a linear relationship is adequate for multiple regression models. But, in some circumstances, particular modifications or elaborations of the model and assumptions are desirable; subject matter theory, the data, or both may suggest some non-linear specification. For example, economic processes such as demand and production functions are best modeled by non-linear relationships. This, in effect, increases the complexity of the modelling process since
functions which contain non-linear parameters and variables are always more difficult to estimate.

Nevertheless, with the use of linearizing transformation procedures, it is often possible to convert some apparently non-linear functions into linear ones so that they can be dealt with by the classical linear regression procedure. In business and economic applications, the most commonly used non-linear formulation is the log-linear model, which postulates a linear relationship among the logarithms of the original variables. A simple non-linear function expressed as:

\[ y = ax^b \]

can be converted into a linear equation by using logarithms. By taking logarithms of both sides of the equation, the linearized function becomes:

\[ \log y = \log a + \beta \log x \]

Essentially, the logarithmic transformation hopes to achieve a specification that is more linear in the transformed variables, with error terms that have more equal variances and a more normal distribution. In that case, inference based on the log-linear model would be more reliable than inference based on the linear model. In addition, the use of the logarithmic scale means that relationships are interpreted in terms of proportions instead of their actual values. It is often argued that a relative measure of economic relationships is more realistic than an absolute one. However, according to Newbold and Bos (1990), it does not mean that the logarithmic transformation is invariably appropriate in all cases, even though the log-linear specification has often been found useful in modelling the relationships among business and economic time series.

8.4.3 Non-linear Regression Algorithms

In situations where it is impossible to apply any linearizing transformation to convert a non-linear function into a linear one, a non-linear regression algorithm instead of the usual regression procedure will have to be used.
These non-linear regression algorithms are iterative procedures which are capable of estimating several non-linear parameters concurrently. Some of the more popular procedures are the Maximum Likelihood (ML) estimator, the Generalised Least Squares (GLS) estimator, the Cochrane-Orcutt algorithm and the Prais-Winsten algorithm. They can still be based on the principle of minimising the sum of the squares of errors or depart completely from this and attempt to estimate the parameters by maximising the log-likelihood function. The last two procedures are specifically used to transform regression equations to remove the effect of autocorrelation, and simultaneously estimate the non-linear parameters involved. The application of the Cochrane-Orcutt algorithm will be illustrated in Chapter 10.

A major problem with the fitting of non-linear regression is that it is very slow compared with linear regression, especially when there are several parameters to be estimated. These mathematically sophisticated iterative procedures are devised to help lessen the problem but the high computing cost has often discouraged the use of non-linear regression. However, it is progressively changing with the enormous increase in speed and power of computers over the past few years. As a consequence, more interest is being taken in these techniques, greatly expanding the scope and flexibility of regression analysis.

8.5 Construction demand modelling and forecasting applications

Literature indicates that the methods used for demand prediction in the construction industry are mainly extrapolative, that is, usually involving projection of trends, with subjective adjustments (Hillebrandt, 1974 and Fellows, 1987). Little use is made of more sophisticated techniques such as univariate or multivariate time-series analysis, econometrics and the leading indicators approach. Sparkes and McHugh (1984) made a similar observation in the British manufacturing industry. They noticed that although an increasing number of companies appreciated the importance of forecasting, the methods used were predominantly naive. A lack of knowledge and working experience, particularly for methods involving the use of computers, was found to be the reason for the lack of use of more advanced forecasting techniques. According to Oshobajo and Fellows (1989), the use of more sophisticated techniques would provide more reliable predictions for the construction industry and consequently minimise the effects of periodic shocks that have characterised the industry. Several demand models have since been developed using more advanced forecasting methods. The following is a detailed description of these models, highlighting the
8.5.1 Investigation of leading indicators for the prediction of UK contractors' workloads (total new orders)

Oshobajo and Fellows (1989) explored the applicability of the Leading Indicators technique to model and predict contractors' new orders in the UK. The study identified variables that indicate trends of contractors' workload and used these identified leading indicators to build causal models for forecasting new orders. At the same time, a time-series model was also developed, using the univariate Box-Jenkins approach, to serve as a benchmark with which to compare the forecast performance of the causal model built using leading indicators.

The Leading Indicators technique was applied because the construction industry is susceptible to economic fluctuations, which makes the fore-knowledge of turning points and the magnitude of the fluctuations in economic trends provided by the leading indicators of great significance. The study used both government and professional organisations' published data. New Orders was used as the dependent variable, and the independent variables comprised Investment (GDFCF), RIBA New Commissions, RIBA Work at Production Drawing Stage and Interest Rate. The first stage of the modelling process entailed an inspection of the time series of these variables to determine if features such as seasonal, cyclical and irregular components, and trend are present in them. Time plots for each of the variables were produced to facilitate the inspection of each series. The second stage involved the testing of the series for non-stationarity in their variances so as to determine the appropriate transformations required. The method suggested by O'Donovan (1983) was adopted which involved dividing each of the series into subsets relating to the size of the seasonal periods. The standard deviation and the mean for each series were plotted against each other to highlight the underlying pattern in the respective series. When no evidence of non-stationarity in the variance was indicated, the appropriate differencing of the respective variables was adequate to yield stationary series. These stationary series were subsequently used to build the models. The procedure suggested by Box and Jenkins (1976), which involves the stages of identification, estimation and diagnostic checking, was used to develop the univariate time-series model. For the Leading Indicators model, the classical decomposition technique and cross-correlation analysis were applied to determine the relationship between the dependent variable and the independent variables, followed by the use of multiple regression analysis to build regression equations of the identified leading indicators to predict New Orders.
The study identified Interest Rate as the only leading indicator of New Orders. Both the classical decomposition technique and the cross-correlation analysis revealed that Interest Rate consistently led New Orders inversely by one to two quarters at a significant level. RIBA New Commissions was found to be a coincident indicator of New Orders. Alternative models were computed by regressing the dependent variable New Orders on different time lags of both Interest Rate and New Orders itself. Forecasts were subsequently made using these models. The predictive accuracy of the models was compare with that of the benchmark model. It was concluded that the performance of the Leading Indicators models improved forecast accuracy by 5 to 12 per cent.

8.5.2 Thai construction industry: demand and projection

The study by Tang et al. (1990) was an attempt to gain further insight into the demand for construction activities in Thailand. The two objectives of the study were: to estimate the demand functions for construction activities in Thailand; and to project the growth of the Thai construction industry for the next five years. Three types of construction were considered: residential, non-residential and 'other' (mainly public projects). The demand function for each type of construction was estimated using regression analysis.

To develop regression models, the most important task is to determine suitable independent variables. In the study, specific factors that affect the demand for residential construction were found to include National Income per Capita, Relative Price Index, Rate of Household Formation, Size of Population and Interest Rate. Those for demand for non-residential construction comprised Corporate Savings, Industrial Production Index, Number of Tourists, Gross Domestic Product and Exports. Factors found to affect the demand for 'other' construction were Government Revenue, Value-added from Public Utilities and Government Expenditure. These various factors were respectively used to estimate the demand functions for residential, non-residential and 'other' construction using the Stepwise regression technique. This technique selects the significant factors and combines them to estimate the demand function for each type of construction. Those factors found to be insignificant at the 20 per cent confidence level were omitted. A linear relationship was assumed in the demand functions of residential and 'others' construction, and a log-linear relationship was specified for non-residential construction. The estimated demand functions were subsequently used to project total demand for construction in three different scenarios. Each scenario assumed different growth rates of the social and economic factors used for estimating the demand functions.
The results of the Stepwise regression analysis indicated that National Income per Capita, Relative Price Index, Size of Population and Interest Rate were the major determinants of demand for residential construction. Industrial Production Index and Corporate Savings were the determinants identified for non-residential construction, while Government Revenue and Value-added from Public Utilities were those identified for 'other' construction. The demand models were found to have fairly high R-square values, indicating their goodness of fit. The projection of total demand for construction produced favourable results for the Thai construction industry over the next five years, especially for public construction which will play a significant and dominant role in the growing Thai economy, accounting for over half of the total construction.

8.5.3 Preliminary investigation into formulating demand forecasting model for industrial construction

Leading indicators were employed by Killingsworth (1990) to develop a demand forecasting model for industrial construction using multiple regression analysis. The study involved, firstly, identifying the determinants that were highly correlated with industrial construction; secondly, identifying which of these determinants were leading indicators of industrial construction; thirdly, determining the time lag between the movements in these indicators and the corresponding movements in industrial construction; and finally, applying a multiple regression procedure using industrial construction and the lagged indicators to compute the demand model. United States government data were used for the study. They were used to quantify industrial construction and its determinants namely, population, interest rates, economic shocks, demand for products, surplus manufacturing capacity, business expectations and profit expectations.

The modelling process comprised the following procedures:

1) The data were first adjusted to remove the effects of inflation and random fluctuations.

2) The data were then transformed into relative terms, that is, the annual rate of change was calculated for industrial construction and each of its determinants.

3) Line graphs were plotted to compare industrial construction volume with each of its determinants.

4) The graphs were analysed to identify the determinants that were highly correlated
with industrial construction, and to determine the time lags of these leading indicators.

5) A multiple regression procedure was applied to compute the demand model using industrial construction as the dependent variable and the lagged indicators as the independent variables. A linear relationship was assumed in the model.

6) Test statistics were used to determine the model accuracy and reliability.

The results of the graphical analysis indicated that correlation exists between industrial construction and interest rates, demand for products and economic shocks at a consistent time lag of two, three and six quarters respectively. The other determinants were not found to be correlated with industrial construction. The regression model developed based on the three identified leading indicators produced a high adjusted R-square value, indicating that the model was significant in explaining the dependent variable. Based on this high R-square value, it was assumed that the demand model would produce forecasts of acceptable accuracy.

8.5.4 Models of UK private sector quarterly construction demand

Models of UK private sector quarterly construction demand were developed by Akintoye and Skitmore (1994) using *a priori* selected leading indicators. Their study was prompted by a clear indication of an increasing level of private investment in the UK over the period of 1974 to 1988, making it appropriate to consider the nature of private sector demand. The models were produced for three groupings of private sector new orders: housing, commercial and industrial construction. The indicators selected for the study were GNP, price level, real interest rate, unemployment and manufacturing profitability. They were regarded as the general factors of construction demand for the UK and used as independent variables in the models.

The modelling process for each type of construction involved several stages. Firstly, time lags of eight quarters for each independent variable were specified as it was anticipated that there would be lead relationships between the dependent and independent variables. This was based on a priori considerations that more than one time period was required to exert the influence of all the past changes in an independent variable. Hence, a maximum lag of eight quarters was used as this was considered a long enough period for the influence of a change in a factor on the private-sector construction demand to be completed. To this effect, nine in-sample data (zero to eight quarters
lead) were created for each of the variables, giving a total of 45 independent variables applied in each initial model. Secondly, the strengths of the relationships between construction demand and these lagged variables were estimated by a standard ordinary least-squares (OLS) step-wise multiple regression procedure. Thirdly, the variables that met the step-wise regression analysis criteria were selected. Finally, the demand functions using only the selected variables were re-estimated. A log-linear relationship was assumed for all three models based on two reasons: the need to determine elasticities of response of the dependent variable to independent variables; and the original data of the independent variables exhibited non-linear scatter when plotted against the dependent variable.

The step-wise regression procedure identified the significant indicators of the three types of construction. For housing construction demand, it was found that demand is significantly correlated with price level, GNP and real interest rate. The relationships with unemployment and manufacturing profitability were unsupported by the data. For commercial construction demand, its trends could be explained by the trends in real interest rate, manufacturing profitability, GNP and unemployment level. Demand for industrial construction was found to be correlated with only GNP and manufacturing profitability. Several conclusions were drawn from these results. Firstly, only housing construction demand is responsive to changes in price level, unlike commercial and industrial construction demand. This suggested that private sector housing demand may increase with an elastic response to a given fall in the price level. Secondly, the positive inelastic relationship between industrial construction demand and GNP supported the importance of national income or economic conditions in private-sector industrial investment. Thirdly, the negatively and inelastically relationship between unemployment and commercial construction demand implied that increasing unemployment has a declining effect on commercial construction investment generally; and commercial building demand responds immediately to changes in real interest rates. Finally, as expected, manufacturing profitability was only relevant to private sector commercial and industrial construction investment. Although the log-linear regression models had high R-square values, indicating good-fit models, their ex-post forecasting performance was poor. It was concluded that further variables need to be investigated and included to improve the accuracy of these models.

8.6 A critique of the prevailing forecasting methods used for construction demand modelling and prediction

The review of past works in construction demand modelling revealed that all the studies had adopted the technique of multiple regression. Although the Leading Indicators technique had been applied
in the studies by Oshobajo and Fellows (1989), and Killingsworth (1990), it only served as a means of selecting the independent variables for the regression models. Strictly speaking, the Leading Indicators technique is intended only to be used to forecast the timing of turning points and not the size of the forthcoming downswing or upswing (Ascher, 1978; and Granger and Newbold, 1987). Hence, it would be misleading to suggest that the classical Leading Indicators technique had been used in these two studies.

Based on these reviewed studies, it is possible to generalise that the multiple regression technique is the predominant method employed in the current state of construction demand modelling and forecasting research. Although the frequent application of one particular method should not be considered as a limitation, the lack of objectivity in its choice would be. Hence, there is a need to evaluate the suitability of the multiple regression technique by comparing it with other forecasting methods.

The main objective of developing demand models for construction is to facilitate predictions of future levels of demand. Forecasting literature (Makridakis et al., 1982; Lawrence, 1983; Mahmoud, 1984; and Thomas, 1993) have always cited accuracy as the most vital attribute of a prediction model, since an important consideration in the decision to use a quantitative model is its accuracy. They have also highlighted that this attribute plays an important role in the selection and testing of different forecasting techniques. Empirical studies (Armstrong, 1978; Makridakis and Hibon, 1979; Slovic, 1972; and Makridakis et al., 1982) have also shown that levels of forecasting accuracy vary according to the type of method adopted, emphasizing the need to explore different techniques in order to establish the most accurate one. More often, in construction demand modelling, when a model is not producing accuracy forecasts, it is attributed to the poor choice or inadequate use of modelling variables (Akintoye and Skitmore, 1994), or the presence of autocorrelated errors (Killingsworth, 1990). The suitability of the forecasting method was never in doubt. If it is true that the level of accuracy largely depends on the type of forecasting method used, construction demand modelling research to date has failed to focus on an issue fundamental to its existence and, that is, to compare and evaluate the forecasting accuracy of the methods used to model and predict demand. So far, only Oshobajo and Fellows (1989) have attempted to compare the accuracy of two forecasting methods, namely, the pseudo Leading Indicators technique and the univariate Box-Jenkins approach.

Another common attribute of these regression models is that they mostly adopt a linear form. A
shortcoming of the regression method is that it forces models into a form whereby they can be treated by linear least squares during the model estimation stage (Jenkins 1979). This is generally regarded as inefficient because the linear functional assumption may not be capable of modelling the true relationship of the variables. In reality, relationships are seldom linear, making this functional assumption even more tenuous. In order to account for non-linearity, some demand models (Tang et al., 1990; and Akintoye and Skitmore, 1994) have assumed a log-linear form. Again, the imposition of a functional form to fit the data would essentially cause the latent relationship of the variables to be ignored. Regarding modelling methods that rely on functional assumptions, Newbold and Bos (1990) indicated that it is quite unrealistic to hope that any simple model and associated assumptions can provide a perfectly accurate description of the complexity that exists in the real world.

The issues discussed in this section have highlighted two major limitations of the current state of research in construction demand modelling and forecasting. Firstly, it is felt that the current state of research has been disadvantaged through not having a formal means of critically evaluating one forecasting method relative to another. This is largely caused by a general lack of interest in exploring alternative methods of modelling and forecasting construction demand. The focus of past studies seems to be on establishing the procedures of building the model, without taking a step further to examine the performance of the model. Model building should not be treated as a means to an end. It should be supported with a formal testing procedure, using accuracy measures as a basis of evaluation and comparison. Secondly, it is of the opinion that the prevalent use of the linear form in regression models produces demand models that may well fit the sample data but then exhibit miserable predictive performance. This is because the predictive ability of the model relies heavily on the precision of the functional specification, emphasizing the importance of this task. Any inaccuracy in this respect essentially undermines the whole basis of this predictive model. To assume that relationships take on simple forms like linear or log-linear is simply ignoring the fact that complexities exist in the real world. Hence, the practicality of these demand models is gravely in doubt.

8.7 Chapter summary

This chapter has provided a broad overview of forecasting, ranging from the general need to forecast to the specific use of different forecasting methods to model and predict demand for construction.
In Section 8.2, two main reasons were cited for the need to forecast. Firstly, forecasts are needed in order to reduce the degree of uncertainty in the future; and secondly, accurate predictions of the future improve the efficiency of the decision-making process. Several examples were also given to justify this need.

A theoretical overview of quantitative forecasting methods was provided in Section 8.3. There are essentially two main groups of quantitative forecasting methods, time series and causal methods. Time-series methods assume explicitly that the underlying pattern of a data series can be identified solely on the basis of its historical data. In contrast, causal methods rely on the cause and effect relationship between the dependent and independent variables. As such, they are also known as explanatory models. Regression techniques are most commonly applied to develop causal models. They range from simple linear regression models to complex econometric models.

Focusing on building causal models using regression methods, Section 8.4 elaborates on the theoretical aspects of the regression approach. Basic principles of the classical linear regression, regression applying linearizing transformation and non-linear regression algorithms were discussed. It was noted that the possibility of fitting non-linear models has greatly increased the scope and flexibility of regression analysis.

Section 8.5 proceeded to describe several construction demand modelling and forecasting applications. The review of past works in demand modelling and forecasting focused on more recently developed models as they had adopted more sophisticated techniques. Models prior to them mainly used simple extrapolative methods which did not produce good forecasts. The first study employed the pseudo Leading Indicators technique to model and predict UK contractors' workload. The univariate Box-Jenkins approach was adopted as a benchmark method for comparison with the causal models based on their predictive ability. It was found that the causal model built using leading indicators could improve forecast accuracy by 5 to 12 per cent. The second study involved the use of multiple regression techniques to predict demand on the Thai construction industry. Factors affecting the demand for residential, non-residential and 'other' construction were used as independent variables to build the demand models by adopting multiple linear and log-linear regression analysis. The demand functions were subsequently used to project the growth of the construction industry for the next five years. The third study formulated a demand forecasting model for industrial construction using US leading indicators. Multiple regression analysis was also used to model the relationship between the leading indicators and the demand for industrial construction.
The final study adopted leading indicators and regression methods to model and predict UK's private sector quarterly construction demand. Multiple log-linear regression analysis was applied to develop demand models for private residential, commercial and industrial construction.

Based on the review of past works, a critique of the prevailing forecasting methods used to model construction demand was provided in Section 8.6. Several issues were highlighted and discussed. Firstly, it was noted that the multiple regression technique is the predominant method used to develop construction demand models. Therefore, there is a need to evaluate this method by comparing its predictive ability with other forecasting methods in order to justify its suitability. Secondly, it was observed that a linear form was mainly assumed in these models. Otherwise, a log-linear form was specified for non-linear models. In either case, functional assumptions were used, ignoring the latent relationship of the variables. In this respect, it was argued that these models are impractical because modelling methods that rely on functional assumptions, such as regression techniques, seldom provide an accurate description of the complexity of real-world situations. Finally, it was concluded that construction demand modelling research to date had failed to focus on the fundamental issue of comparing and evaluating the forecasting accuracy of the methods used to model and predict demand. It was attributed to the lack of a formal means of critically evaluating one forecasting method relative to another.
CHAPTER 9

ARTIFICIAL NEURAL NETWORKS: 
THEORY AND APPLICATIONS

9.1 Introduction

This chapter is an introduction of a promising paradigm in Artificial Intelligence (AI) computing technology known as Artificial Neural Networks (ANNs). In essence, the chapter provides an overview of ANNs technology, focusing on the concepts, constructs and terminology, and a description of some of the key ANN paradigms and their applications.

ANNs are formally defined in Section 9.2. It comprises a general definition of ANNs and another simpler, but less rigorous, definition. Several distinct characteristics of ANNs are listed in Section 9.3 to highlight their potential usefulness.

Section 9.4 introduces the fundamental terminology and the basic mathematical concepts used to describe and analyse ANN processing. In a broad sense, ANNs consist of three elements: an organised topology (geometry) of interconnected processing elements; a method of encoding information; and a method of recalling information. The sub-sections on processing elements and network topologies provide a description of neural system topologies; those on threshold elements and, again, processing elements provide an overview of ANN recall; and those on memory and learning provide some insights into ANN encoding.

Some key ANNs paradigms and their applications are described in Section 9.5. It includes a mathematical, and sometimes an algorithmic, representation of the paradigms; a discussion of their strengths and limitations; and a brief summary of their current and potential applications.

Finally, Section 9.6 details some applications of ANNs to forecasting. More specifically, the focus is on two main areas of forecasting: economic and financial forecasting; and construction-related forecasting. The usefulness of ANNs in forecasting is illustrated in these applications.
9.2 Definitions

ANNs have been described as neurally inspired models of brain and behaviour (Arbib, 1964; and Grossberg, 1982). They are computational devices whose architectures are elementary emulations of the networks of nerve cells inside the brain. Although they do not, and are not able to replicate the complex biological detail of the human brain, they provide sufficient insight into the biological processing of the brain. Hecht-Nielsen (1988 & 1990:2) offers the following as a general definition of an ANN:

"A neural network is a parallel, distributed information processing structure consisting of processing elements (which can possess a local memory and carry out localized information processing operations) interconnected together with unidirectional signal channels called connections. Each processing element has a single output connection which branches ("fans out") into as many collateral connections as desired (each carrying the same signal - the processing element output signal). The processing element output signal can be of any mathematical type desired. All of the processing that goes on within each processing element must be completely local: i.e., it must depend only upon the current values of the input signal arriving at the processing element via impinging connections and upon values stored in the processing element's local memory."

A simpler, but less rigorous, definition of an ANN is given by Simpson (1987) as:

"...a nonlinear directed graph with weighted edges that is able to store patterns by changing the edge weights and is able to recall patterns from incomplete and unknown inputs."

The key elements of most ANN descriptions are the distributed representation, the local operations, and non-linear processing. Simpson (1990) highlighted that these attributes emphasize two of the primary applications of ANNs, and they are:

1) situations where only a few decisions are required from a massive amount of data; and

2) situations where a complex non-linear mapping must be learned.
9.3 Characteristics of ANNs

Following the definitions of ANNs, several of their distinct characteristics can be listed as follows:

1) An ANN is composed of a number of very simple processing elements that communicate through a rich set of interconnections with variable weights or strengths.

2) Memories are stored or represented in an ANN in the pattern of variable interconnection weights among the processing elements. Information is processed by spreading, constantly changing patterns of activity distributed across many processing elements.

3) An ANN is taught or trained rather than programmed. It is even possible to construct systems capable of independent or autonomous learning; some ANNs are capable of learning by trial and error.

4) The operation of an ANN is implicitly controlled by three properties: the transfer function of the processing elements; the details of the structure of the connections among the processing elements; and the learning law that the system follows.

5) An ANN naturally acts as an associative memory, that is, it inherently associates items it is taught, physically grouping similar items together in its structure. An ANN operated as a memory is content addressable; it can retrieve stored information from incomplete, noisy, or partially incorrect input signals.

6) An ANN is able to generalise: it can learn the characteristics of a general category of items based on a series of specific examples from that category.

7) An ANN is highly fault tolerant. It continues to work even after a significant fraction of its processing elements and interconnections have become defective. Its performance degrades slowly and smoothly as these elements fail.

8) An ANN automatically acts as a processor for time-dependent spatial patterns, or spatiotemporal patterns.
9) An ANN can be self-organising. Some ANNs can be made to generalise from data patterns used in training without being provided with specific instructions on exactly what to learn.

9.4 Theoretical foundations of ANNs

This section comprises an explanation of the relationship between real neural systems and artificial neural systems, and an overview of the foundational concepts, constructs and terminology used to describe ANN models. The objective is to introduce the fundamental terminology of ANNs and provide the basic mathematical concepts used to describe and analyse ANN processing. The three distinct areas covered include: (1) a description of the ANN organised topology of interconnected processing elements; (2) insights into the method of encoding information; and (3) an overview of the method of recalling information.

9.4.1 Real and artificial neural systems

The human information processing system consists of the biological brain. The basic building block of the nervous system is the neuron, the cell that communicates information to and from the various parts of the human body. The neuron consists of a cell body called a soma, several spine-like extensions of the cell body known as dendrites, and a single nerve fibre called the axon that branches out from the soma and connects to many other neurons. A neuron accepts input from a large number of similar neurons at connections called synapses, which are located at the dendrites. The neuron processes these inputs, and sends its output to other neurons through the axon. Essentially, an axon carries the signal away from the neuron, and the dendrites receive the signal from other neurons. The nervous system is constructed of billions of neurons with the axon from one neuron branching out and connecting to as many as 10,000 other neurons. All the neurons, interconnected by axons and dendrites that carry signals regulated by synapses, create a neural network.

The structure of an ANN mimics this very simplified view of biological neural architecture. It has only three building blocks: processing elements (an artificial model of the biological neuron); interconnections (the paths or links between processing elements); and synapses (the junction where an interconnection meets a processing element). These correspond to the neurons, axons and synapses of biological systems. Each processing element receives a large number of individual input...
signals that together constitute an input pattern. This input pattern causes the processing element to reach some level of activity. If the activity is sufficiently strong, the processing element, like its biological analogue, generates a single output signal that is transmitted over the interconnections to other processing elements or to the final output of the network. Figure 9.1 shows how a processing element operates as a simple threshold unit, that is, it collects inputs and produces an output only if the sum of the inputs exceeds an internal threshold value. As a threshold unit, the processing element collects signals at its connections and adds them together. Once the accumulated signal strength exceeds the threshold, a signal is sent through the interconnections. The total input signal is always compared to an internal threshold value of the processing element, and propagates an output signal if the threshold is exceeded. ANNs are created by interconnecting many of these simple processing elements into a network.

9.4.2 Processing elements

Processing elements (PEs), also known as nodes, short-term memory, neurodes, or threshold units, are the ANN components where most, if not all, of the computing is done. They are equivalent to the neurons in the biological neural system. Figure 9.2 displays, in more detail, the anatomy of a generic PE. The input signals come from either the environment or outputs of other PEs and form an input vector:

\[ A = (a_1, \ldots, a_n), \]

where \( a_i \) is the activity level of the \( i \)th PE or input. Associated with each connected pair of PEs is an adjustable value called a weight, connection strength, interconnect, or long-term memory. Different weights are used for the input signals in order to emphasize their individual significance to the PE. The collection of weights that abuts the \( j \)th PE, \( b_j \), forms a vector:

\[ W = (w_{j1}, \ldots, w_{jn}), \]

where the weight \( w_{ij} \) represents the connection strength from the PE \( a_i \) to the PE \( b_j \). Sometimes there is an additional parameter \( \theta_j \) modulated by the weight \( w_{oj} \) that is associated with the inputs. This term is considered as an internal threshold value that must be exceeded in order for there to be any PE activation. The weights \( W_j \), their associated PE values \( A \), and the possible extra parameter \( \theta_j \),
Figure 9.1 A Processing Element as a Simple Threshold Unit

Figure 9.2 A Generic Processing Element illustrating the Threshold Function
are used to compute the output value $b_j$. This computation is typically performed by taking the product of $A$ and $W_j$, subtracting the threshold, and passing the result through a threshold function $f()$. Mathematically, this operation is defined as:

$$b_j = f\left(\sum_{i=1}^{n} a_i w_{ij} - w \theta\right)$$

9.4.3 Threshold functions

Threshold functions, also referred to as activation functions, signal functions, or transfer functions, map a PE's infinite domain of the inputs to a pre-specified range of the output. In essence, the threshold function is capable of altering the local memory of the PE. The combined input signals will activate the threshold function, which will then transfer information to the output path, if the strength of the inputs exceeds a certain activity level. Four common threshold functions are the linear, ramp, step and sigmoid functions. Others used include Tanh, Sine and Cosine. Usually, the threshold function is arbitrarily chosen through many trial experiments. Hence, no one function is superior to another since each performs differently depending on the characteristics of the data set used. According to Simpson (1990), the Sigmoid threshold function is the most pervasively applied threshold function. This S-shaped function is a bounded, monotonic, non-decreasing function that provides a graded, nonlinear response. Two common Sigmoid functions are the logistic function which has saturation levels of 0 and 1, and the hyperbolic tangent which has saturation levels at -1 and +1. The equations of these two Sigmoid functions are given below.

Logistic function: $S(x) = \frac{1}{1 + e^{-x}}$, and

Hyperbolic tangent: $S(x) = \text{tanh}(x)$.

9.4.4 Topology characteristics

ANN topologies, or architectures, are formed by organising PEs into fields, slabs, or layers, and linking them with weighted interconnections. Characteristics of these topologies include connection types, connection schemes and field configurations.
There are two primary connection types: excitatory and inhibitory. Excitatory connections increase the PE's activation and are typically represented by positive signals. Inhibitory connections decrease a PE's activation and are typically represented by negative signals. These connections need not be distinguished; a portion of the connections abutting a PE may have negative weights and the remainder have positive weights.

The three main PE interconnection schemes are intra-field, inter-field, and recurrent connections. Intra-field connections, also referred to as intra-layer connections, are connections between PEs in the same layer of PEs. Inter-field connections, or inter-layer connections, are connections between PEs in different fields or layers. Recurrent connections are connections that loop and connect back to the same PE. Inter-field connection signals propagate in one of two ways, either feedforward or feedback. Feedforward signals only allow information to flow amongst PEs in one direction. During feedforward recall, the input signal is passed through the memory and produces an output response in one pass. On the other hand, feedback signals allow information to flow amongst PEs in either direction and/or recursively. During feedback recall, the input signal is passed through the memory and produces an output response that is, in turn, fed back into the memory until the signal and response cease to change. Figure 9.3 illustrates the difference between the feedforward and feedback recalls.

Field or layer configurations combine fields of PEs, information flow and connection schemes into a coherent architecture. Field configurations include intra-field feedback, inter-field feedforward and inter-field feedback. A field that receives input signals from the environment is called an input field or input layer, and a field that emits signals to the environment is called an output field or output layer. Any fields that lie between the input and output fields are called hidden fields or hidden layers. Essentially, hidden layers have no direct contact with the environment and are, therefore, different from input and output layers. An ANN topology is formed by organising PEs into fields and linking them with weighted interconnections. Four common ANN topologies are: a one-layer intra-field feedback ANN; a two-layer feedforward ANN; a two-layer feedback ANN; and a three-layer feedforward ANN. In essence, a topology comprising more than two layers would require the use of one or more hidden layers.
Figure 9.3 An illustration of the difference between feedforward and feedback recall
9.4.5 Memory and recall

In order for ANNs to learn and recall information, they must have a memory system that can store information and recall it on demand. According to Caudill and Butler (1989), learning and memory are intimately entwined: there can be no learning if there is no memory. Aspects of ANN memory comprise pattern types, memory types and mapping mechanisms.

ANNs store two types of patterns: spatial patterns and spatiotemporal patterns. A spatial pattern is a single static image. A spatiotemporal, or space-time, pattern is a sequence of spatial patterns. A convenient analogy is to consider a spatial pattern as a frame of a movie, and a spatiotemporal pattern as the entire movie. Between the two, spatial patterns are more commonly adopted, since many ANN paradigms are spatial pattern classifiers.

There are three different types of spatial pattern matching memories: random access memory; content-addressable memory; and associative memory. Random access memory (RAM) is the type of memory found in conventional computers and it maps addresses to data. Content-addressable memory (CAM) is found in some computers and signal processing equipment and it maps data to addresses. An associative memory maps data to data. Essentially, ANNs act as CAM and associative memory. When an ANN is acting as a CAM, it stores data at stable states in some memory matrix W. When an ANN is acting as an associative memory, it provides output responses from input stimuli. Associative memory is similar to human memory in that it recalls complete situations from partial information. It plays an important role in pattern recognition and information-processing applications.

There are two primary ANN mapping mechanisms: autoassociative and heteroassociative mappings. An ANN is autoassociative if its memory, W, stores the vectors or patterns $A_1$, ..., $A_m$. Autoassociative memories are often used to reconstruct partial or error-prone patterns into their original forms or to optimise certain operations research problems. An example of autoassociative application is character recognition. An ANN is heteroassociative if W stores the pattern pairs $(A_1, B_1), ..., (A_m, B_m)$. Heteroassociative memories map one set of patterns to another. An example of heteroassociative application is financial-trend analysis.

There are also two basic ANN recall mechanisms: nearest-neighbour recall and interpolative recall. Nearest-neighbour recall finds the stored input that most closely matches the stimulus and responds
with the corresponding output. Interpolative recall accepts a stimulus and interpolates, in a possibly nonlinear manner, from the entire set of stored inputs to produce the corresponding output.

9.4.6 Learning or training method

Learning takes place when there is any change in the memory, \( W \). Mathematically, it is defined as:

\[
Learning = \frac{dW}{dt} \neq 0
\]

All learning or training methods can be classified into two categories: supervised learning and unsupervised learning. Supervised learning is a process that incorporates an external teacher and/or global information. It requires pairs of data consisting of an input pattern and the correct result; training data must contain the solution that the network is expected to provide, which is sometimes difficult to obtain. A series of case history, either actual or contrived, is therefore required. In supervised learning, external control of the training process is also necessary, such as, deciding when to stop the training. On the contrary, unsupervised learning, also referred to as self-organisation, is a process that incorporates no external teacher and only relies upon local information and internal control. Unsupervised learning self-organises presented data and discovers its emergent collective properties. It classifies input patterns internally and has no need for an expected result. Hence, the data requirements for unsupervised learning are less demanding.

Learning methods form the backbone of all ANN paradigms. In essence, learning models in ANN are rules or procedures that tell a PE how to modify its synaptic weights in response to stimuli (Caudill and Butler, 1989). The following sub-sections briefly describe some popular learning algorithms.

9.4.6.1 Error-correction Learning

Error-correction learning is a supervised learning procedure that adjusts the connection weights between PEs in proportion to the difference between the desired and computed values of each PE in the output layer. If the desired value of the \( j \)th output layer PE is \( c_j \) and the computed value of the same PE is \( b_j \), then a general equation for changing the connection strength \( w_{ij} \) is:
\[ \Delta w_{ij} = \alpha a_{i} (e_{j} - b_{j}) \]

where \( w_{ij} \) is the memory connection strength from \( a_{i} \) to \( b_{j} \); and
\( \alpha \) is the learning rate, typically \( 0 < \alpha \ll 1 \).

The error-correction learning algorithm is adopted by one of the most popular ANN paradigms, Backpropagation. This ANN paradigm will be fully discussed in Section 9.5.3.

9.4.6.2 Reinforcement Learning

Reinforcement learning is similar to error-correction learning in that weights are reinforced for properly performed actions and punished for poorly performed actions. The difference is that error-correction learning requires an error value for each output layer PE to derive a vector of error values, and reinforcement learning requires only one value to describe the output layer's performance, that is, a scalar error value. The scalar success or failure value is provided by the environment. Bailey and Thompson (1990) considers this learning algorithm as a compromise between supervised and unsupervised training as it requires an input and only a grade or reward signal as an output. Hence, training data requirements are less stringent than those for supervised learning.

9.4.6.3 Hebbian Learning

Hebbian learning, named after Donald Hebb (1949) who articulated the concept of correlation learning but not the mathematical formalisation, is the adjustment of a connection weight according to the correlation of the values of two PEs it connects. The original statement of Hebb's law reads as follows:

"When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."

The simplest mathematical form of this learning rule, the simple Hebbian correlation, where the weight value \( w_{ij} \) is the correlation or multiplication of the PE \( a_{i} \) with the PE \( b_{j} \), is expressed as:

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The net effect of this process is that the strength of the interconnection from A to B increases. This implies that B will become more sensitive to A's stimulus after appropriate training has occurred.

9.4.6.4 Competitive and Cooperative Learning

Competitive and cooperative processes are described as ANNs with self-exciting recurrent connections and neighbour-inhibiting (competitive) and/or neighbour-exciting (cooperative) connections. They are essentially self-organising systems that can learn by themselves as the PEs in the network compete for the privilege of learning. Competitive learning, introduced by Grossberg (1972 and 1976), is a pattern of classification procedures for conditioning inter-layer connections in a two-layer ANN. In the simplest form where "winner takes all", competitive learning works in concert with recall in the following manner:

1) an input pattern is presented to the input layer \( F_A \) of PEs;

2) the input layer PEs send their activations through the \( F_A \) to \( F_B \) inter-layer connections to the \( F_B \) layer;

3) each \( F_B \) PE competes with the others by sending positive signals to itself (recurrent self-excitation) and negative signals to all its neighbours (lateral neighbour-inhibition); and

4) eventually the \( F_B \) PE with the greatest activation will be singularly active and all others will be nullified. The \( F_B \) PE with the largest activation is called the \( F_B \)-winner.

Once the competition is complete, adjustment or conditioning of the \( F_A \) to \( F_B \)-winner inter-layer connections takes place. This means that only the weights of the connections emanating from the winning \( F_B \) PE are adjusted, leaving all other connections unaffected. In this respect, only the winning PE is allowed to learn, which is a distinctive feature of a competitive learning network. In other networks, all the PEs adjust their weights when an input pattern is presented to them.
9.4.7 Stability and convergence

ANN processing is typically governed by two bodies of mathematics: global stability and convergence. Global stability is the eventual stabilization of all PE activations from any initial input. Convergence is the eventual minimisation of error between the desired and computed PE outputs. Stability is a notion usually associated with feedback recall, and convergence is a notion usually associated with supervised learning.

Globally stable ANNs are defined as nonlinear dynamical systems that rapidly map all inputs to fixed points (Chetayav, 1961). These fixed points, also known as limit points, convergence points, or equilibria, are where information can be deliberately stored. Although global stability guarantees all inputs are mapped to a fixed point, it does not guarantee that it will map all inputs into the desired fixed point. There are three main theorems that are used to prove stability for a wide range of ANN paradigms that employ feedback during recall. They are: the Cohen-Grossberg theorem for showing the stability of non-adaptive autoassociators; the Cohen-Grossberg-Kosko theorem for showing the stability of adaptive autoassociators; and the ABAM theorem for showing the stability of adaptive heteroassociators. Details of these three theorems can be found in Simpson (1990).

Convergence is a means of analysing the ability of a given learning procedure to properly capture the mapping between presented data. Hence, convergence is strictly related to the learning in a system. If the mapping converges to a fixed value, or to some fixed set, then the learning procedure is properly capturing the mapping. The degree of error that is measured during learning describes how well this mapping is being acquired. There are two convergence methods that are common to many ANN paradigms: convergence with probability 1; and convergence in the mean-square sense.

Convergence with probability 1 is defined as:

$$\lim_{{n \to \infty}} p\{x_n = x\} = 1$$

where \(p\{x\}\) represents the probability of \(x\).
Convergence in the mean-square sense is defined as:

$$\lim_{n \to \infty} E \left| \frac{x_n^2}{x_i^2} - x_i \right| = 0$$

where $E\{x\}$ represents the estimated value of $x$.

9.5 Some major ANN paradigms and their general applications

ANN paradigms are generally classified according to their inherent encoding and recall qualities. The two inherent encoding qualities of ANN paradigms are supervised and unsupervised learning, and their two inherent recall qualities are feedforward and feedback recall. This section focuses on a particular classification of paradigms, and that is, supervised learning and feedforward recall ANNs. This class of paradigms, especially the Backpropagation paradigm, has been widely applied to forecasting, which is the subject of interest in this study. The following sub-sections on the Perceptron, the ADALINE and most importantly, the Backpropagation paradigm, provide an account of the historical development of ANNs.

9.5.1 Perceptron

The birth of ANN is often taken to be the seminal work of McCulloch and Pitts (1943). They developed a revolutionary model comprising two-state threshold units. It is a highly simplified model of biological neurons. The working of this neuron model is based on the nature of its threshold units. If the unit’s summed input is greater than a specified threshold value, and if there is no inhibitory input to the unit, the unit outputs a 1. If the summed input is less than the threshold or if there is any inhibitory input to the unit, the output is 0. This model could possibly be the first true connectionist model because it has simple processing elements arranged partly in parallel and are capable of
manipulating any finite number of logical expressions. However, there was a fundamental problem with the McCulloch and Pitts threshold units. There was no knowledge of how to connect the units to make them solve arbitrary problems. In essence, there was no learning law developed for the model.

Rosenblatt (1958) added the learning law to the McCulloch-Pitts threshold unit and hence, invented the Perceptron. Extensive studies were also carried out by him subsequently (Rosenblatt, 1960 & 1962). He was able to demonstrate mathematically that the Perceptron training algorithm can always solve any linearly separable problem in a finite number of training trials. Rosenblatt's enthusiasm drew many other researchers into the field, resulting in significant progress in the span of a few years. Modifications to this training algorithm increased. There are actually several ANN topologies that have been used within the framework of Perceptron. The elementary Perceptron is a two-layer, heteroassociative, nearest-neighbour pattern matcher that stores pairs of patterns by using the Perceptron error-correction procedure. The model assumes a fixed threshold and uses a binary response similar to the McCulloch and Pitts' model. Details of this elementary Perceptron are given in Simpson (1990).

However, by the mid-1990's there was a fall in interest in Perceptron systems, partly due to a growing realisation that the class of problems they can solve is quite limited and partly to a lack of hardware and software with which to continue the research. Finally, a report by Minsky and Papert (1969) demonstrated the limitations of the Perceptron training algorithm. The Perceptron is poor at generalisation, it requires lengthy supervised learning and it cannot encode nonlinear separable classifications. It never became a viable application system; as a practical system, it was a failure. But as a foundational building block towards successively more powerful models, the Perceptron has been a huge success. This is evidenced by the triumph of more sophisticated paradigms, such as ADALINE and Backpropagation.

The Perceptron is ideally suited to pattern matching applications that are inherently linear and only require a two-class response. Areas where the Perceptron has been applied are: knowledge processing (Gallant and Balachandra, 1986); pattern recognition (Roberts, 1960; and Rosenblatt, 1962); speech processing (Rosenblatt, 1962; and Burr, 1988); sequence recognition (Rosenblatt, 1962); and image processing (Rosenblatt, 1962; and Kollias and Anastassiou, 1988).
9.5.2 ADALINE/MADALINE

Following the invention of the Perceptron, the next great work in the field of ANNs is by Widrow and Hoff (1960), who introduced the ADAptive LINear Element, or ADALINE network. It was equipped with a new powerful learning algorithm known as the Widrow-Hoff, Delta rule, or Least Mean Squared (LMS) learning law, which has the potential to learn more quickly and accurately. The adaptive PE is a threshold logic unit with variable connection strengths. The weights on the synapses change if information on the input, actual and desired outputs is available.

The ADALINE is a two-layer feedforward (perceptron) ANN, and a configuration of several ADALINES placed in the familiar two-layer feedforward topology is called the Multiple ADALINE, or MADALINE. The MADALINE is a heteroassociative, nearest-neighbour pattern matcher that stores pattern pairs, using the LMS error-correction encoding procedure. It encodes patterns by minimising the least mean square error between the computed and desired outputs of each PE in the output layer. The mean-squared error is minimised by changing the inter-layer connection weights in a way that follows the error gradient to its minimum.

The LMS is also a learning law that finds linear solutions and its analytical form resembles that of the Perceptron. The main functional difference is in the computation of the output by the learning algorithms. The Perceptron forces the net output to be mapped into a final output of 1 or 0, but the LMS learning law uses the net output directly without any further mapping. The goal of the LMS learning law is to minimise the average (squared) distance from the desired output to the actual output. This distance, or error, is computed by subtracting the actual output from the desired response and is used to change the connection weights based on the LMS, or Delta rule. The LMS, or Delta rule used to make this weight adjustment is expressed by the simple equation (Caudill, 1988):

\[ W_{\text{new}} = W_{\text{old}} + \alpha E \cdot X / |X|^2 \]

where, \( W \) is the weight vector before (old) and after (new) the weights are adjusted;
\( E \) is the error value (or the difference between the desired and actual outputs);
\( X \) is the input pattern vector;
\( |X| \) is the length or magnitude of the input pattern vector; and
α is the learning constant (i.e. a measure of the speed of convergence of the actual weight vector to the ideal weight vector).

Eventually, the LMS learning law should converge to the minimum distance. This iterative technique of minimisation is known as gradient descent. The weights are constantly being revised in the direction of the greatest descent. A more detailed explanation of the LMS learning law is provided in Weiss and Kulikowski (1991).

The LMS algorithm is the most pervasive of all ANN encoding algorithms. Unlike the Perceptron, the ADALINE is still in widespread use today. The number of researchers who have analysed, altered and extended the LMS algorithm is large. The strengths of ADALINE or MADALINE ANNs include its capacity to hold more patterns, and its well understood mathematics. Limitations of this paradigm include the lengthy encoding time and the restriction to linear mappings. ANN related work adopting the LMS algorithm is primarily focused upon adaptive pattern matching and control. The application areas where the ADALINE, or MADALINE, has been employed are: control (Widrow and Smith, 1964; and Tolat, 1988); pattern recognition (Widrow, 1962; and Widrow, Winter and Baxter, 1988); image processing (Waxman et al., 1988); noise cancellation (Widrow et al., 1975; and Widrow and Stearns, 1985); and antenna systems (Widrow, Mantey and Griffiths, 1967).

9.5.3 Backpropagation

The learning algorithms discovered so far have only been able to handle linear classifications. This was considered as a major limitation in both the Perceptron and ADALINE for solving more complex real-world problems. The first gradient descent approach to training multi-layered ANNs came from mathematics and was developed by Amari (1967), who introduced a single hidden layer PE to perform non-linear classification. Amari's approach was in the right direction, but it still was not a complete description of how to develop a multi-layered mapping. When Rumelhart, Hinton and Williams (1986), a group of cognitive and computer scientists, exploited the power and potential of Backpropagation, the scientific community became excited about this ANN paradigm. It has had the immediate effect of answering the key argument that led to the demise of ANN research in the late 1960's and 1970's.

Backpropagation is a learning algorithm that relies on backward-error propagation. Each input, or
training pattern presented to a Backpropagation network is processed in two stages. In the first stage, the input pattern presented to the network generates a forward flow of activation from the input to the output layer. In the second stage, errors in the network's output generate a flow of information from the output layer backward to the input layer. It is this feature that gives the network its name. This backward propagation of error is used to modify the weights on the interconnections of the network, allowing the network to learn.

Backpropagation networks are always hierarchical, that is, they always consist of at least three layers of PEs: an input layer, an output layer, and a hidden, or middle, layer. Essentially, the input layer accepts patterns from the outside world, the output layer presents the network's response back to the outside world, and the hidden layer, or layers, builds an internal model of the way the input patterns are related to the desired outputs. Hence, the hidden layer, and thus the hierarchical structure of the system, is the source of the improved internal representation of Backpropagation ANNs. Physically, this representation exists within the synapses of the interconnections of the hidden layers of the network; the higher the inter-layer connectivity is, the better is the ability of the network to build a representation or model of the input data. The backward transmission of errors allows Backpropagation ANNs to generate a sophisticated and accurate internal representation of the input data.

The Backpropagation ANN is trained by a generalised version of the LMS learning law, known as the Generalised Delta rule. Basically, the LMS learning algorithm is completely linear; the weighted sum of the inputs is directly used to activate the output unit and no additional mapping by an activation function is made. If this linear function is applied in the Backpropagation network, it would not be useful because the hidden layer would not be effectively utilised. Hence, a non-linear activation, or transfer, function is required. In Backpropagation ANNs, a logistic, or sigmoidal, activation function is used. The characteristics of this S-shaped curve are important to the operation of a Backpropagation network; it levels off at some lower and upper value of the summed input and it always increases between these limits. The derivative, or slope, of a sigmoid curve is shaped like a bell, with the largest values in the mid-range of the summed inputs and very small values at both extremes. Multiplying the error correction term by this bell-shaped derivative function ensures that the weights on the PE will change only slightly as the summed input approaches either very low or very high values. If a linear function had been used, the weight change could not be limited for low or high activation values as the slope of a linear transfer function would be constant and have the same value for all values of the summed input. In essence, the sigmoidal transfer function helps to
ensure the stability of the network as a whole since it assists in preventing the weights from
cyclically fluctuating through a range of values. Effectively, this would ensure that the weights settle
to a set of stable values.

In summary, the Backpropagation learning law is an iterative gradient algorithm designed to
minimise the mean squared error between the actual output and the desired output of a multilayer
feed-forward Perceptron. It requires continuous differentiable non-linearities such as the non-linear
sigmoid transfer function. Figure 9.4 shows an elementary three-layer Backpropagation ANN. With
reference to this graphical representation, the Backpropagation training algorithm can be outlined
as follows:

1) Forward Activation Flow

During the first stage, the network is presented with a set of inputs and the desired output. The
summed input, $I$, is determined by multiplying each input signal by the weight of its interconnection:

$$I = f \left( \sum w_i * x_i \right)$$

where, $w$ and $x$ are the weights and input signals respectively; and

$f(x)$ is the activation function of the PE.

For a Backpropagation network, this function should be sigmoidal:

$$f'(x) = \frac{1}{1+e^{-(x+T)}}$$

where, $T$ is a simple threshold, $x$ is the input; and

$e$ is the mathematical exponential constant.

By computing the summed input, $I$, using the non-linear sigmoidal function, the actual output of the
PE is obtained.

2) Backward Error Flow

In the second stage, the actual output of the network is compared with the desired output. The difference between them, or the error, is used to adjust the weights to complete this iteration of the network. To compute the weight changes, the Generalised Delta rule is applied:

$$\Delta W_{t+1} = \alpha E X / |X|^2 + \beta \Delta W_t$$

where,
- $\Delta W_{t+1}$ is the current change in the weight vector;
- $E$ is the error value (or the difference between the desired and actual outputs);
- $X$ is the input pattern vector;
- $|X|$ is the length or magnitude of the input pattern vector;
- $\alpha$ is the learning constant (i.e. a measure of the speed of convergence of the actual weight vector to the ideal weight vector);
- $\beta$ is the momentum term; and
- $\Delta W_t$ is the previous change in the weight vector.

The momentum term is a constant term, and it is included to ensure that if the previous weight change was in a particular direction, it attempts to make the current weight change in more or less the same direction. This speeds up convergence and keeps the network from falling into a local minimum. In a local minimum, the training procedure gives a false convergence and little additional progress is made in reducing the error distance.

During this stage, the errors are also backpropagated for each output-layer PE to the hidden layer using the same interconnections and weights as the hidden layer used to transmit outputs to the output layer. The error of each hidden-layer PE is also computed using the Generalised Delta rule, and is again used for weight adjustment of its interconnections.

The complete cycle of forward activation propagation and backward error propagation constitutes one iteration of the network. The network is usually trained with many input patterns and hence,
many of such iterations are involved. This iterative procedure will stop once the error distance has converged to zero or a minimum specified value. Generally speaking, as the number of hidden-layer PEs increases, the training-error rate should decrease. This means that one can always add sufficient number of hidden-layer PEs to eventually reach a zero error distance. However, if the hidden layer is too large, it will encourage the network to memorise the input patterns rather than generalise the input into features. This reduces the network's ability to handle unfamiliar inputs after the training is complete. On the other hand, a hidden layer with too few PEs will drastically extend the number of training iterations and will likely reduce the accuracy of the recall. Hence, a compromise between the ability to generalise and the level of recall accuracy has to be made when determining the number of PEs to be used in the hidden layer.

Backpropagation is one of the most important ANN paradigms available today because it is reasonably simple to implement and works extremely well for a wide variety of applications. Backpropagation ANNs are often more versatile than other mapping networks, and can generally learn with greater reliability. They have the ability to store many more patterns and most importantly, to acquire arbitrarily complex non-linear mappings. Their primary limitation is that they require so many presentations of the input data to learn, and each presentation requires two passes through the network, forward and backward. Each pass is also relatively complex computationally. All these factors contribute to their extremely long training time and their inability to explain precisely any arbitrary mapping procedure. Often, they have been termed as a "black box" since they lack explanation capabilities. They do not provide users with details of how they reason with data to arrive at particular conclusions. Hence, they are not suitable for applications where explanation of reasoning is critical.

The number of studies and applications of Backpropagation is becoming vast. Nevertheless, the primary application of the Backpropagation ANN is any situation that requires the acquisition of a complex non-linear mapping. The main application areas include: image processing (Dodd, 1987; and Glover, 1988); speech processing (Watson, 1987); prediction/optimisation (Werbos, 1988; Castelaz; 1988; Dutta and Shekha; 1988; and Kimoto et al., 1990); diagnostics (Bounds et al., 1988); control (Josin, Charney and White, 1988); knowledge processing (Hinton, 1986; and Kaplan and Johnson, 1988); character recognition (Khotanzad and Lu, 1988); and signal processing (Gorman and Sejnowski, 1988).
Figure 9.4 Topology of an Elementary Three-layer Backpropagation Artificial Neural Network
9.6 Application of Backpropagation ANNs to forecasting

As already mentioned, the application areas of the Backpropagation learning algorithm are diverse owing to its ability to handle complex non-linear problems. However, the main interest of this study is in the use of ANNs for forecasting. Treleaven and Goonatilake (1994) highlighted that Backpropagation ANNs provide a relatively easy way to model and forecast non-linear systems without the need for any functional assumptions. This gives them an advantage over many current or traditional statistical methods used in economics and finance which are primarily linear. The following sub-sections describe some existing applications of Backpropagation ANNs for economic, financial and construction-related forecasting. Since the use of ANNs for forecasting is still at its exploratory stages, most of these studies entail a comparison of the forecasting performance of ANNs with some traditional forecasting methods.

9.6.1 Economic and financial forecasting

In the business and financial sectors, decision-support systems are increasingly being used in a wide range of classification, prediction and optimisation tasks. Essentially, decision-support systems transform large amounts of quantitative data into intelligible classifications by spotting trends and patterns. Until recently, the primary means of spotting trends in business and financial data was through the use of traditional statistical methods such as statistical clustering and regression analysis (Farnum and Stanton, 1989). Presently, a new generation of computing techniques such as ANNs, has proved to be extremely effective in finding patterns for a variety of complex financial tasks. Some applications of ANNs to economic and financial forecasting are briefly described below.

Dutta and Shekhar (1988) adopted the use of ANNs to predict the ratings of corporate bonds. Bonds issued by a company are traded just like stocks of a company. Independent organisations rate the risk of repayment of these bonds. They assess the ability of a company to repay these bonds at a given time at the agreed interest rate. The methods used by the rating agencies to make such assessments are kept strictly confidential. Hence, a method is needed to predict the ratings of corporate bonds so that it can be used as a guide to make investment decisions about a particular company. There have been many attempts to produce models of corporate bond ratings using regression analysis. Models constructed using regression techniques have an average accuracy of about 60 per cent. Dutta and Shekhar used a Backpropagation ANN to forecast corporate bonds
with 10 input variables describing various aspects of the financial status of the companies. These variables included cash and assets, debt proportion, profit and sales ratios, working capital and growth rates. The proposed ANN achieved a prediction accuracy of about 82 per cent. This was an improvement of about 20 per cent over the linear regression model based on the same data.

Kimoto et al. (1990) used a variation of the Backpropagation algorithm to predict the movements of the Tokyo Stock exchange index. The ANN was trained on four years of historical data which included technical indicators such as interest rates, foreign exchange rates and turnover rates. The output of the network was the decision of whether to buy or sell the stocks. A comparison of the performance of the ANN was made with a multiple regression model. It was found that the trading recommendations of the ANN for a period of three years have shown considerable accuracy over the multiple regression model. A similar study was undertaken by Chuah (1992), applying the New York Stock exchange index. He developed an ANN to predict stock index returns. The performance of the ANN was compared with a benchmark linear model. It was found that the ANN outperformed the linear model in predicting whether returns are higher or lower than the Treasury Bill rate. However, its prediction of the magnitude of the excess return is no better than the linear model.

Varfis and Versino (1990) applied the Backpropagation algorithm to carry out univariate economic time-series forecasting. The main objective was to compare the Backpropagation ANN's performance with the widely used Box-Jenkins approach, a traditional univariate time-series forecasting technique. The economic time-series data used were the production or turnover indices of the manufacturing and energy production industries provided by the Statistical Office of the European Community. The relative error percentages of the two methods were evaluated. It was found that the ANN and the traditional Box-Jenkins approach have very similar forecasting performance. It was concluded that an ANN model is capable of solving, with good accuracy, a non-stationary time-series forecasting task. Performance comparison with the widely used 'classical' method suggests that the ANN approach is worth considering.

Windsor and Harker (1990) attempted to predict the annual movements of up to 14 financial indices simultaneously using a Backpropagation ANN. The objective was to determine the optimum number of input indices and hidden units for the ANN in order to produce the best prediction results. Different numbers and combination of input indices were used to build several ANNs, using different numbers of hidden units. The results showed that the best prediction was obtained from an ANN that used only two indices, the Share Index and Interest Rate. When the two index fit was plotted
against the number of hidden units, it was discovered that four hidden units gave the best prediction. It was concluded that with the choice of appropriate index targets and optimum network parameters, a Backpropagation ANN is able to perform better than other alternative methods such as multiple linear autoregression.

9.6.2 Construction-related forecasting

It is widely believed that construction is more volatile than other sectors of the economy (Hillebrandt, 1984; and Newcombe et al., 1990). Construction variables such as demand, output and price are often subject to substantial fluctuation, creating an element of uncertainty in the construction industry. The need for forecasting, the application of traditional methods and their limitations have been discussed in the previous chapter. Successful applications of ANNs to forecasting, especially in the fields of economics and finance, have encouraged the adoption of this AI technique in construction-related forecasting. These studies are briefly described here.

Gaarslev (1991) and McKim (1993) focused their work on examining construction tender bids. Gaarslev applied the technique of ANNs to examine the relationships between variables in the bidding process. His work is a re-investigation of the work by Broemser (1968). The four independent variables used were number of bidders, estimated cost, percentage of work not subcontracted and the project duration. and the dependent variable was the lowest bid. Data from 76 construction projects were collected and analysed. Although McKim adopted the same set of data for his study, he extended his objective to include the comparison of the predictive capabilities of a traditional statistical method and an ANN. The traditional method adopted was the multiple linear regression analysis. His comparative study found that the ANN produced a lower standard error compared to that produced by the regression model. It was concluded that an ANN can outperform traditional statistical methods in analysing construction-related data as well as in predicting construction-related events. This is because the unique nature of ANNs are particularly well-suited to solving non-linear and multivariate problems which are commonly found in the area of construction management.

Similarly, Goh (1996) evaluated the performance of the Backpropagation ANN and the multiple regression technique in predicting construction demand in Singapore. A total of 12 independent variables were used to develop the models based on quarterly data from 1975 to 1993. They consisted of economic indicators that were identified as significantly related to residential
construction demand. A relative measure, the Mean Absolute Percentage Error (MAPE), was used to compare the forecasting accuracy of the models. The MAPE values computed for the ANN model and the multiple regression model were 1.31 per cent and 6.99 per cent respectively. It was concluded that the ANN model was able to produce more accurate forecasts of demand for residential construction in Singapore than the traditional multiple regression model because of its ability to handle non-linearity.

9.7 Chapter summary

Artificial neural networks (ANN) are mathematical models of theorised mind and brain activity. This chapter introduced the essence of this relatively new AI computing technology by providing: (1) definitions of ANNs; (2) an explanation of the relationship between real neural systems and artificial neural systems; (3) an overview of the foundational concepts, constructs and terminology used to describe ANN models; (4) a description of three key ANN paradigms and their general applications; and (5) a review of several applications of ANNs specifically for forecasting economic, financial and construction variables.

The chapter began with Section 9.2 where some definitions of ANN were provided. The definitions highlighted two primary applications of ANNs. They are situations where only a few decisions are required from a massive amount of data, and where a complex nonlinear mapping must be learned. In order to describe ANNs further, several distinct characteristics of ANNs were given in Section 9.3. They essentially summarised how an ANN operates, focusing on its unique methods of encoding and recalling information.

Section 9.4, by itself, fulfilled one of the main objectives of this chapter. It introduced the fundamental terminology of ANNs and provided the basic mathematical concepts used to describe and analyse ANN processing. The three key areas covered include: a description of the ANN organised topology of interconnected processing elements; insights into the method of encoding information; and an overview of the method of recalling information. Each of these areas were addressed in separate sub-sections dealing with processing elements, threshold functions, topology characteristics, memory, learning or training, and stability and convergence. The relationship between real and artificial neural systems was also discussed.
Next, some major ANN paradigms and their general applications were covered in Section 9.5. The ANN learning laws described were the Perceptron, the ADALINE/MADALINE, and the Backpropagation. Together, they provided an account of the historical development of ANNs. In short, the Perceptron marked the birth of ANN with the invention of the two-state threshold unit and the Rosenblatt error-correction procedure. It was followed by the ADALINE which adopted the concepts of the Perceptron but applied the Delta or LMS learning law. So far, these learning paradigms were only capable of handling linear classifications. The invention of the Backpropagation learning law subsequently broadened the capabilities of ANNs to include the handling of complex non-linear mappings. It was made possible with the application of the Generalised Delta rule which utilises hidden layers and a non-linear transfer function. Backpropagation has since become one of the most important ANN paradigms and it works extremely well for a wide variety of applications.

Finally, the chapter focused on the use of ANNs for forecasting. Section 9.6 reviewed several applications of ANNs to economic, financial and construction-related forecasting. More specifically, the areas covered include the prediction of corporate bond ratings, stock exchange indices, economic indicators, financial indices, construction tender bids, and construction demand. These applications mainly involved complex multivariate classification problems where traditional regression analysis was unable to provide satisfactory predictions. The comparative studies showed that ANNs generally outperformed traditional statistical methods.
CHAPTER 10

CONSTRUCTION DEMAND MODELLING USING ALTERNATIVE FORECASTING APPROACHES:
THE CASE OF RESIDENTIAL CONSTRUCTION IN SINGAPORE

10.1 Introduction

The objective of this chapter is to examine the performance of alternative forecasting approaches to modelling and predicting construction demand. In the past, regression methods have predominated, especially linear techniques, without any justification for their choice. Hence, there are doubts as to whether non-regression or even non-linear regression techniques can outperform linear regression ones. This results in a need to discover the forecasting abilities of different regression techniques, linear and non-linear, and compare them with a non-regression method in order to determine if improvements in predictive accuracy can be obtained.

The Singapore residential sector has been chosen for the case-study. A review of this sector, including the need to forecast its construction demand, is given in Section 10.2. Details of the data and methodology adopted for the case-study are also explained in this section.

In Section 10.3, a brief description is given for the factors to be used to model Singapore's residential building construction demand. In particular, the relationship between each of these factors and demand for residential building construction is theoretically examined. The seven economic indicators concerned are: Building tender price index; Bank lending for housing; Population; Housing stock (additions); National savings; Gross fixed capital formation for residential buildings; and Unemployment rate.

The regression methods considered in the study are namely, the Multiple Linear Regression, the Multiple Log-linear Regression and the Autoregressive Non-linear Regression Algorithm. The application of these techniques to build demand models for Singapore's residential sector is discussed in Section 10.4 separately.

Section 10.5 examines the application of a non-regression method, the Artificial Neural Networks technique, to model Singapore's residential building construction demand. It includes a brief discussion on the method and a full description of the components of the derived model.
The demand models developed in this chapter are applied in Section 10.6 to produce forecasts. The accuracy of the forecasts are evaluated and compared. This allows the predictive abilities of the various techniques to be assessed comparatively.

A summary and discussion of the findings are given in Section 10.7. This is followed by a general discussion on the strengths and weaknesses of the alternative forecasting approaches in Section 10.8.

10.2 The Singapore Residential Sector: a case study

The following sub-sections give a review of the residential sector in Singapore; explain the need to forecast construction demand in this sector; and describe the data and methodology adopted for the case-study.

10.2.1 A review of the Singapore Residential Sector

The Singapore residential sector experienced five distinct phases over the past two and a half decades, which include upturns and downturns of the country's demand for residential construction.

Over the period of 1960 to 1977, total residential construction had been rising steadily except for the slight decline experienced in 1974. It was during this period when the Housing Development Board's (HDB) first three five-year building programmes were launched and completed. Public-sector housing construction dominated the first phase, with a total of about 250,000 units built to house up to 850,000 people.

During the second phase (1978-1979), the residential construction sector experienced negative growth of 17 and 7 per cent in 1978 and 1979 respectively. This was mainly due to the slack in private residential property development and the slowdown in the construction of flats by the HDB as the bulk of backlog in demand for public housing had been met.

Improved business confidence in Singapore's economic growth in the early eighties led to the rapid investment in the residential property market. In 1980, Singapore achieved the highest real Gross Domestic Product growth rate of 9.7 per cent. Hence, the years between 1980 and 1984 marked the third phase. After the significant decline in the late seventies, residential investment turned around to grow sharply. In 1982, residential construction reached the highest growth of 74 per cent for the
entire period in consideration, mainly attributable to the government allowing the use of Central Provident Funds for the acquisition of private residential property which created a resurgence of interest in the residential market. Both the massive five-year building programme of the HDB and a boom in private condominium development contributed to the rapid growth during this phase. In 1983, development of large-scale residential projects, particularly private condominiums, continued to be high. However, the growth in residential construction slowed down sharply to 18 per cent in 1984. A glut in the property market had appeared and there were very few projects initiated as a result of an oversupply of private residential units.

The next four years (1985 - 1989) represented the fourth phase which saw overall investment in residential properties plummeting drastically, with prices falling to a low in 1985 and 1986 owing to the poor performance of the economy. In particular, the number of public residential units completed dropped from a peak of 78,288 in 1984 to 29,149 in 1988 and only 12,152 in 1989 (SBEM, 1991). Although there was a major reduction in public-sector housing investment, the private sector was able to maintain stable growth, reflecting the increased market demand for private-sector developments. The private residential property market also benefited from the strong economic growth over the early 1980's resulting in an average of 3,750 new units per annum completed since the commencement of 1980. The stock market crash in October 1987 did not influence the private residential market, indicating that there were more owner-occupiers and less speculators in the market.

The fifth phase (1990 - 1994) witnessed a gradual recovery, with a steady increase in the supply of new private residential units of 3,709 in 1990; 3,791 in 1991; 4,382 in 1992; 4,969 in 1993; and 6,713 in 1994 (Department of Statistics, 1995). The annual rate of growth in demand was between 6 and 9.5 per cent over this period of time. Public-sector housing demand also increased from Sing$1350 million in 1990 to Sing$3.044 million in 1994, in terms of value of contracts awarded. With strong investments in this sector during this phase, prices even managed to remain fairly stable despite the face of uncertainty caused by the Gulf War.

10.2.2 The need to forecast residential construction demand in Singapore

In land-scarce Singapore, residential properties have always been of great interest to the government and people. Typically, "residential construction constitutes the largest, in terms of units, and most homogeneous group in the construction family" (Tang et al., 1990:250). Incidentally, many studies relating to construction and property investments have been undertaken on the residential sector.
In Singapore, this sector has often been regarded as one of the most important owing to its large percentage share in the total value of construction contracts awarded per year. The detailed figures of the value of contracts awarded from 1986 to 1994 are given in Table 10.1. It shows that the residential sector had a share of between 32 and 50 per cent over this period of time. The sector's fluctuating demand patterns have also generated interests in predicting its future performance. Since the slowdown in the late 1980s, demand for residential properties has been growing steadily in the early 1990s. A peak is anticipated in the mid-1990s, which will be followed by a major decline. Therefore, in recent years, more public attention has been attracted especially since it is widely perceived that the sector is on the verge of the next trough of the real estate cycle in time to come.

Table 10.1 Value of contracts awarded per year (in Sing$ million)

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</tr>
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<tbody>
<tr>
<td>All sectors</td>
<td>3898</td>
<td>4040</td>
<td>3491</td>
<td>5501</td>
<td>8034</td>
<td>7874</td>
<td>12832</td>
<td>10587</td>
<td>11679</td>
</tr>
<tr>
<td>Residential sector</td>
<td>1492</td>
<td>1639</td>
<td>1586</td>
<td>1737</td>
<td>2695</td>
<td>2685</td>
<td>5262</td>
<td>4638</td>
<td>5883</td>
</tr>
<tr>
<td>% share of residential sector</td>
<td>38</td>
<td>40</td>
<td>45</td>
<td>32</td>
<td>34</td>
<td>34</td>
<td>41</td>
<td>44</td>
<td>50</td>
</tr>
</tbody>
</table>


All sectors comprise residential, commercial, industrial, institutional & others and civil engineering works.

With the share of the residential sector still growing and a downturn in demand to be expected in the near future, there is an increasing need to identify, objectively, a forecasting technique which can produce accurate demand forecasts for this important sector of the economy.

10.2.3 Data and methodology

The dataset required for the case-study has been identified in Chapter 6 and is shown in Appendix 1. To reiterate, the Stepwise procedure has selected seven economic indicators that are significantly related to demand for residential building construction in Singapore and, they are: Building tender price index; Bank lending for housing; Population; Housing stock (additions); National savings; Gross fixed capital formation for residential buildings; and Unemployment rate. Demand for residential building construction is represented by the statistical series "Gross floor area of residential developments commenced". For each variable, the time-series data comprise quarterly records spanning between 1975 and 1994. In total, there are 77 quarterly datapoints; the first 72 to be used for building the models, and the remaining 5 for testing the models. Effectively, it means
that the models will be tested on a dataset they have not seen before so that their predictive abilities can be determined more objectively.

In the first stage of the case-study, three different regression techniques are applied to model the dataset namely, the Multiple Linear Regression, the Multiple Log-linear Regression and the Autoregressive Non-linear Regression Algorithm. The SPSS for Windows (Release 6.0) statistical analysis software is adopted in the study to carry out these regression procedures. The three regression models are subsequently used to produce forecasts based on the unseen dataset.

In the second stage, the Artificial Neural Networks (ANN) technique is applied to the same dataset. The Backpropagation learning algorithm is implemented using the NeuroForecaster (version 4.1a) software. Once the training or learning process is completed, the ANN model is also used to generate forecasts based on the unseen dataset.

The final stage involves the computation of the prediction errors for each of the models. The relative measure of forecasting accuracy, known as the Mean Absolute Percentage Error (MAPE), is adopted. The predictive ability of the models is then compared using this relative measure.

10.3 A review of the factors influencing residential construction demand

The seven economic indicators chosen to model residential building construction demand in Singapore are reviewed here. The following is a brief description of each of these indicators, highlighting their close relationship with demand for residential building construction.

a) Building tender price index

A building tender price index can be best described as one figure that reflects the general movement of prices in the construction industry for each period of time, relative to the base period (Tysoe, 1981). It combines the relative changes of the most important factors involved such as building costs, levels of market competition, contractors' risks and profits. In economic literature, the relationship between demand and price is a recurring theme. Past studies (Runeson and Bennett, 1983; McCaffer et al., 1983; and Runeson, 1988) have shown that construction price levels are dependent on the demand for construction. Taylor and Bowen (1987) have also established a causal relationship between demand and price, showing that a fluctuating demand for construction leads to fluctuating prices and vice versa. In a recent study involving demand analysis, Akintoye and
Skitmore (1994) have established construction price as one of the significant factors of private sector housing construction demand in the UK.

b) Bank lending

Housing is generally regarded as a consumption good and is typically the largest single item purchased by an average household. Hence, such expenditures are mainly financed by mortgage loans from banks or other financial institutions. Many writers, in particular Rosen (1979), Stone (1983), Briscoe (1988) and Ruddock (1992), have highlighted mortgage credit as an important factor influencing the level of demand for housing construction especially in the private sector. In a study of the residential building cycle, Hall and Richardson (1980) found that the major factor that affects builders' perception of demand is the number of loans made to first-time home purchasers. The amount of mortgage loans can, therefore, serve as a good indication of the level of demand for residential construction in general.

c) Population

Demographic influences have often been cited to affect housing demand. Essentially, population growth forms the basic influence on the increases in the demand for housing. Lewis (1965), in his study of population and building cycles, argued further that besides population growth, household formation or even the number of groups of persons wishing to share structurally separate dwellings are more accurate factors affecting housing demand. In his analysis of the population statistics of the Great Britain between 1821 and 1931, he discovered that as a rough approximation, a steady increase in population might be expected to result in more or less steady increases, from one decade to the next, in the stock of houses. While fluctuations in the rate of increase of population should show some similarities to the pattern of building activity. Hillebrandt (1974) also cited population factors as main determinants of basic demand for housing. She implied that governments often determine the level of public housing provision based on the need for new housing as indicated by the rate of population growth. In Thailand for example, the size of population has been identified as having a significant effect on the demand for residential construction (Tang, et al., 1990).

d) Housing stock

The change in housing stock essentially measures the levels of house-building activity in a country. Lewis (1965) examined the interrelationship of three factors namely, population, building activity
and housing stock, and explained that faster growth in population is accompanied by higher levels of building activity and greater net increases in housing stock. On the contrary, a slower growth in population implies lower activity in house-building and smaller net increases in the housing stock. Other writers who regarded housing stock as one of the key determinants of demand for residential construction include Hillebrandt (1974), Briscoe (1988), Raftery (1991) and Ruddock (1992). Besides the size, the condition of existing housing stock is also emphasized.

e) National savings

National savings is a measure of the total savings in an economy, that is, the sum of savings by the private sector and the government. As savings are considered as leakages in the circular flow of income and expenditure, an increase in the level of savings would imply a decrease in the level of consumption and vice versa. Since housing is often regarded as a consumption good, demand for residential construction will be affected by the level of savings, especially household savings. Similarly, a rise in government savings may also imply a reduction in public spending on infrastructure such as roads, dwellings and other forms of fixed investment. However, savings also has a major influence on future investment and interest rates since they are the main source of finance for investment. When national savings are high, the availability of funds for borrowing is reflected by lower interest rates, leading to more investment and spending. In this way, savings are injected back into the economic system through investments.

f) Gross fixed capital formation

Fixed capital formation is a measure of construction output as it accounts for the value of all new construction and all capital alterations or extensions of buildings or works. It has often been used to represent the level of demand for construction since it is generally accepted that there are no statistics of demand, only of output. However, if forward indicators of demand are available, such as value of contractor's new orders or developments granted planning approval, fixed capital formation can act as a useful lagging indicator, confirming the inferences on demand behaviour. In fact, Fleming (1986) suggests that output forecasts can even serve as relevant forward indicators of demand, but their reliability is inevitably subjected to the level of accuracy of the forecasts.

g) Unemployment level

Unemployment is a measure of the total number of people out of work but are ready and able to
work. It is directly related to the economic well-being of a country. Hence, an increase in unemployment or even a declining rate of growth in employment may discourage investment in construction. This is attributable to construction demand being linked to the total purchasing power of the population. As employment is the main source of household incomes which, in turn, are spent on consumer goods and services, increases in unemployment reduce the ability and the willingness of households to spend on expensive items such as housing. Looking at the construction industry as a whole, Akintoye and Skitmore (1994) explained that increases in unemployment may raise the level of financial uncertainty among potential investors in construction and cause them to defer or abandon investments with a resulting reduction in total new construction volume. Unemployment is frequently used as a proxy for the willingness to pay and it often enters demand equations with a negative sign (Evans, 1969).

10.4 Construction demand modelling and forecasting using regression methods

The main objective of this section is to build construction demand models, applying regression methods, and use them to produce forecasts. The accuracy of the forecasts will be examined in Section 10.6, in terms of percentage errors, to establish the predictive ability of these models.

Both linear and non-linear regression techniques are considered here. Linear regression is a more commonly used modelling technique owing to its simplicity in concept and application. However, the possibility of fitting non-linear models, either by means of a linearizing transformation such as the logarithmic transformation, or by the use of a non-linear regression algorithm such as the Cochrane-Orcutt, greatly increases the flexibility of regression analysis. With this in mind, three distinct regression techniques are experimented in the study: the first is the Multiple Linear Regression, the second is the Multiple Log-linear Regression and the third is the Autoregressive Non-linear Regression Algorithm. The application of these techniques to model residential building construction demand in Singapore is fully described below.

10.4.1 Application of the Multiple Linear Regression Technique

The technique of Multiple Linear Regression assumes a linear relationship between the dependent variable on the one hand and the independent variables on the other. Applying this concept to the case-study, the demand function can be expressed as follows:
DEMAND = \( f ( \text{BTPI}, \text{GFCF}, \text{HSELOAN}, \text{POPULATN}, \text{HSESTOCK}, \text{SAVINGS}, \text{UNEMPMT}) \),

where DEMAND is residential building construction demand, BTPI is building tender price index, GFCF is gross fixed capital formation for residential buildings, HSELOAN is bank lendings for housing, POPULATN is population size, HSESTOCK is housing stock (additions), SAVINGS is national savings, and UNEMPMT is unemployment rate.

The statistical analysis is carried out using the Linear-Regression procedure available in the SPSS software. The method of analysis is based on the Ordinary Least Squares (OLS) multiple regression, modelling the linear relationship between the dependent and the independent variables. All the variables specified in the demand function are entered in a single step to derive the results given in Table 10.2.

Table 10.2 Estimated demand function for residential construction using Multiple Linear Regression

<table>
<thead>
<tr>
<th>Dependent variable : DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent variables</td>
</tr>
<tr>
<td>BTPI</td>
</tr>
<tr>
<td>GFCF</td>
</tr>
<tr>
<td>HSELOAN</td>
</tr>
<tr>
<td>POPULATN</td>
</tr>
<tr>
<td>HSESTOCK</td>
</tr>
<tr>
<td>SAVINGS</td>
</tr>
<tr>
<td>UNEMPMT</td>
</tr>
<tr>
<td>(CONSTANT)</td>
</tr>
</tbody>
</table>
R-square = 0.93203; Adjusted R-square = 0.92460;
Standard error = 113.92317; Durbin-Watson value = 0.71661.
Regression: DF = 7; Sum of squares = 11390156.99; Mean squares = 1627165.28.
Residual: DF = 64; Sum of squares = 830623.23; Mean squares = 12978.49.

By summarising the results in Table 10.2, the derived estimated demand function for residential building construction in Singapore, applying the Multiple Linear Regression technique, can be expressed as:

\[
DEMAND = -3127.54 + 3.81 \times (BTP) + 1.29 \times (GFCF) + 0.11 \times (HSELOAN) + 1525.87 \times (POPULATN) - 0.52 \times (HSESTOCK) - 0.06 \times (SAVINGS) + 126.20 \times (UNEMPMT).
\]

A problem often associated with multiple regression analysis is the existence of multicollinearity. It occurs because too many variables have been put into the model, and a number of variables may be measuring similar phenomena. It often results in coefficient estimates that are not statistically significant or have incorrect signs or magnitude (Myers, 1986). Since the results in Table 10.2 indicate that the coefficient estimates of all the independent variables have met a 5 per cent or, at least, a 10 per cent significance level, only the signs of these estimates have to be verified at this stage.

The signs for all the independent variables seem reasonable except for the variable UNEMPMT. The analysis established a positive relationship between the demand for residential building construction and the rate of unemployment. This is a departure from economic theory where an inverse relationship is to be expected. As elaborated earlier, the economic well-being of a country can be implied from its level of unemployment. The rate of unemployment increases when aggregate demand decreases, as a result of reduced spending by the government and private consumers, causing investment to decline as well. The reverse is true when the rate decreases. Hence, during a period of rising unemployment, the demand for residential building construction should be expected to fall. However, this may not be the case in Singapore as strictly speaking, its economy has not faced any serious unemployment situation since the sixties. By the early eighties, when many economists came to believe that full employment meant an unemployment rate close to 6 per cent, the rate in Singapore was only 2.6 per cent in 1982 and stood at 3.3 per cent in 1988 (Toh and Low, 1990). The only time when the rate did rise to 6.5 per cent was in 1986 when Singapore experienced a general economic recession. The government immediately intervened and injected about Sing$1.3
billion, which constituted almost 90 per cent of the total annual value of building contracts awarded in the residential sector (Construction Industry Development Board, 1988), into public-sector housing in the hope of stimulating demand in the private sector and also revitalizing the whole economy. This counter-cyclical spending by the government during the only period of rising unemployment in Singapore may help to explain why a positive relationship was found in the analysis. With this justification, it can be concluded that no serious problem of multicollinearity has been detected for this first model.

10.4.2 Application of the Multiple Log-linear Regression Technique

The concept of Multiple Log-linear Regression is based on the postulation that a linear relationship exists between the logarithms of the dependent and independent variables. It is the most commonly used linearizing transformation which allows the possibility of fitting non-linear models. Essentially, a logarithmic transformation is applied to all the variables before any modelling process takes place. Applying this concept to the case-study, the demand function can be expressed as follows:

\[ \log \text{DEMAND} = f (\log \text{BTPI}, \log \text{GFCF}, \log \text{HSELOAN}, \log \text{POPULATN}, \log \text{HSESTOCK}, \log \text{SAVINGS}, \log \text{UNEMPMT}), \]

where \( \log \text{DEMAND} \) is the logarithms of residential building construction demand, \( \log \text{BTPI} \) is the logarithms of building tender price index, \( \log \text{GFCF} \) is the logarithms of gross fixed capital formation for residential buildings, \( \log \text{HSELOAN} \) is the logarithms of bank lendings for housing, \( \log \text{POPULATN} \) is the logarithms of population size, \( \log \text{HSESTOCK} \) is the logarithms of housing stock (additions), \( \log \text{SAVINGS} \) is the logarithms of national savings, and \( \log \text{UNEMPMT} \) is the logarithms of unemployment rate.

Similarly, the statistical analysis is carried out using the Linear-Regression procedure available in the SPSS software. The method of analysis also utilises the OLS multiple regression, modelling the linear relationship between the logarithmic values of the dependent and the independent variables. All the variables specified in the demand function are entered in a single step to derive the results given in Table 10.3.
Table 10.3 Estimated demand function for residential construction using Multiple Log-linear Regression

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient (B)</th>
<th>SE (B)</th>
<th>t-value</th>
<th>Sig t</th>
</tr>
</thead>
<tbody>
<tr>
<td>logBTPI</td>
<td>0.3958</td>
<td>0.1272</td>
<td>3.112</td>
<td>0.0028</td>
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<td>logGFCF</td>
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<td>0.0784</td>
<td>11.937</td>
<td>0.0000</td>
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<tr>
<td>logHSELOAN</td>
<td>0.6891</td>
<td>0.1488</td>
<td>4.630</td>
<td>0.0000</td>
</tr>
<tr>
<td>logPOPULATN</td>
<td>1.8431</td>
<td>1.1981</td>
<td>1.538</td>
<td>0.1289</td>
</tr>
<tr>
<td>logHSESTOCK</td>
<td>-0.2860</td>
<td>0.0628</td>
<td>-4.554</td>
<td>0.0000</td>
</tr>
<tr>
<td>logSAVINGS</td>
<td>-1.8159</td>
<td>0.2261</td>
<td>-8.030</td>
<td>0.0000</td>
</tr>
<tr>
<td>logUNEMPMT</td>
<td>0.4879</td>
<td>0.0798</td>
<td>6.114</td>
<td>0.0000</td>
</tr>
<tr>
<td>(CONSTANT)</td>
<td>11.2634</td>
<td>1.7591</td>
<td>6.403</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-square = 0.89605; Adjusted R-square = 0.88468; Standard error = 0.11085.
Regression: DF = 7; Sum of squares = 6.77918; Mean squares = 0.96845.
Residual: DF = 64; Sum of squares = 0.78648; Mean squares = 0.01229.

From the results shown in Table 10.3, the derived estimated demand function for residential building construction in Singapore, using the Multiple Log-linear Regression, can be summarised as follows:

\[
\text{logDEMAND} = 11.263 + 0.396 \times \text{logBTPI} + 0.936 \times \text{logGFCF} + 0.689 \times \text{logHSELOAN} \\
+ 1.843 \times \text{logPOPULATN} - 0.286 \times \text{logHSESTOCK} \\
- 1.816 \times \text{logSAVINGS} + 0.488 \times \text{logUNEMPMT}.
\]

Similarly, in order to detect the existence of multicollinearity, the statistical significance and the signs of the coefficients of the independent variables have to be verified for this model. Firstly, it is found that all the coefficient estimates have achieved a 5 per cent significance level, except for the variable logPOPULATN where a reasonably acceptable 15 per cent level has also been met. Secondly, it is also noticed that the signs of the coefficients are the same as those derived for the first model. Hence, justification for the contradictory sign of the variable logUNEMPMT would also follow the same reasoning. Based on these two findings, a similar conclusion can be reached and that is, no serious problem of multicollinearity is detected in this second model.
10.4.3 Application of the Autoregressive Non-linear Regression Algorithm

The use of a non-linear regression algorithm, such as the Cochrane-Orcutt, is another means of fitting non-linear models. The Cochrane-Orcutt procedure is effectively a way of introducing a specialized lag structure in a previously static model. It is often applied when autocorrelation is detected in a regression model which is caused by a relationship among the values of the residual term in the sample period. Functional misspecification is a common cause of autocorrelation which produces inefficient regression coefficients with incorrect estimated standard errors. For instance, if the true model is of a non-linear form and a linear one has been specified, strong positive autocorrelation of the residuals will be present. This phenomenon can be detected by means of a Durbin-Watson test. Values of this test statistic range from 0 to 4, with values less than 2 indicating positively correlated residuals and values greater than 2 indicating negatively correlated residuals. In order to eliminate the autocorrelation, the Cochrane-Orcutt algorithm is used to transform the regression equation by taking into account the presence of an autoregressive scheme such as:

\[ u_t = \rho u_{t-1} + e_t \]

where, \( u_t \) is the value of the residual term in the current period \( t \);
\( \rho \) (rho) is the autoregressive coefficient;
\( u_{t-1} \) is the value of the residual term in the previous period \( t-1 \); and
\( e_t \) is the error term in the current period \( t \).

This algorithm is an iterative process which revises the estimates of the regression coefficients and the autoregressive coefficient (\( \rho \)) alternately until convergence is achieved. Effectively, the basic linear regression model:

\[ y_t = \alpha + \beta x_t + u_t \]
is transformed into the following model:

\[ y_t = \alpha (1 - \rho) + \rho y_{t-1} + \beta x_t + \beta \rho x_{t-1} + e_t \]

by subtracting \( \rho \) times the basic model in the previous time period \((t-1)\) from the basic model in the current period \((t)\). Since the equation of the transformed model contains non-linear parameters, the OLS regression technique cannot be used to fit it. Instead, the Cochrane-Orcutt, or a related technique, must be applied to perform what is in reality a non-linear regression. The application of this procedure allows autocorrelation in the residuals \((u)\) to be entirely eliminated once the optimum value of the autoregressive coefficient \((\rho)\) is found since:

\[ u_t - \rho u_{t-1} = e_t \]

The final set of estimated coefficients obtained will not be subject to the problem of autocorrelation because, by assumption, values of the error term \((e)\) are independent of one another.

The procedure described above is performed on the first model of the case-study, that is, the model developed using the Multiple Linear Regression, since autocorrelation has been detected. The Durbin-Watson test statistic (0.71661) is less than 2, indicating positive autocorrelation. The objective here is to re-model the data, taking into account the presence of autocorrelation, by using a non-linear regression algorithm such as the Cochrane-Orcutt technique. Figure 10.1 plots the pattern of the autocorrelations of the residuals of the first model. Based on the Box-Ljung Q statistic and its significance level at each lag, it can be seen that all the autocorrelations are significant, indicating that the residuals are not white noise or random. The general rule for model fitting is that as long as the residuals still display a pattern, it means that the fitted model is not adequate. Since the problem of autocorrelation has been identified earlier, a first-order autoregressive transformation is implemented using the Cochrane-Orcutt procedure. The results of the analysis are given in Table 10.4.
Autocorrelations: RES_1 Residual

<table>
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<tr>
<th>Lag</th>
<th>Corr.</th>
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<th>-.5</th>
<th>-.25</th>
<th>0</th>
<th>.25</th>
<th>.5</th>
<th>.75</th>
<th>1</th>
<th>Box-Ljung</th>
<th>Prob.</th>
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<td>102.656</td>
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</tbody>
</table>

Plot Symbols: Autocorrelations * Two Standard Error Limits .

Total cases: 72 Computable first lags: 71

Figure 10.1 Autocorrelations of the residuals of the Multiple Linear Regression Model
Table 10.4 Estimated demand function for residential construction using a first-order autoregressive transformation

Dependent variable: DEMAND

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient (B)</th>
<th>SE (B)</th>
<th>t-value</th>
<th>Sig. t</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTPI</td>
<td>6.7434</td>
<td>2.7639</td>
<td>2.439</td>
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<td>HSELOAN</td>
<td>0.1193</td>
<td>0.0379</td>
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<td>POPULATN</td>
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<td>-492.337</td>
<td>877.682</td>
<td>-0.561</td>
<td>0.5768</td>
</tr>
</tbody>
</table>

\[ \rho = 0.76298; \text{ Standard error } = 81.426. \]

\[ \text{Residuals: OF } = 63; \text{ Adjusted sum of squares } = 422799.34; \text{ Residual variance } = 6630.255. \]

In order to test the goodness of fit of this model, the autocorrelations of the residuals are plotted again. Figure 10.2 shows the pattern of the autocorrelations and their respective Box-Ljung test statistic. The highly significant statistics at all lags indicate that the autocorrelations are not random, implying that the current model is still inadequate.

At this stage of the analysis, it seems necessary to use a higher-order autoregressive transformation. A second-order scheme is proposed which takes on a more general form:

\[ u_t = \rho_1 u_{t-1} + \rho_2 u_{t-2} + \epsilon_t \]

In this case, the iterative process would have to look for the optimum values of two autoregressive coefficients (\( \rho_1 \) & \( \rho_2 \)), instead of one, in order to eliminate the problem of autocorrelation. The results of the second-order autoregressive transformation is shown in Table 10.5.
Autocorrelations: ERR_2 Error for DEMAND

<table>
<thead>
<tr>
<th>Lag</th>
<th>Corr.</th>
<th>Err.</th>
<th>-1</th>
<th>-0.75</th>
<th>-0.5</th>
<th>-0.25</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>Box-Ljung</th>
<th>Prob.</th>
</tr>
</thead>
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<tr>
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<td>.115</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>13.417</td>
<td>.000</td>
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<tr>
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<td>.061</td>
<td>.115</td>
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<td>.001</td>
</tr>
<tr>
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<td>-.275</td>
<td>.114</td>
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<td>.000</td>
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<td>.113</td>
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<td></td>
<td></td>
<td></td>
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<td>.000</td>
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<td>.104</td>
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<td></td>
<td></td>
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<td>.000</td>
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<tr>
<td>15</td>
<td>.085</td>
<td>.103</td>
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<td></td>
<td>68.752</td>
<td>.000</td>
</tr>
</tbody>
</table>

Plot Symbols: Autocorrelations * Two Standard Error Limits.

Total cases: 72 Computable first lags: 71

Figure 10.2 Autocorrelations of the residuals of the First-order Autoregressive Non-linear Regression Model
Table 10.5 Estimated demand function of residential construction using a second-order autoregressive transformation

Dependent variable: DEMAND

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient (B)</th>
<th>SE (B)</th>
<th>t-value</th>
<th>Sig. t</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTPI</td>
<td>8.8678</td>
<td>1.9260</td>
<td>4.604</td>
<td>0.0000</td>
</tr>
<tr>
<td>GFCF</td>
<td>0.9595</td>
<td>0.1171</td>
<td>8.197</td>
<td>0.0000</td>
</tr>
<tr>
<td>HSELOAN</td>
<td>0.1047</td>
<td>0.0239</td>
<td>4.384</td>
<td>0.0000</td>
</tr>
<tr>
<td>POPULATN</td>
<td>39.297</td>
<td>184.248</td>
<td>0.213</td>
<td>0.8318</td>
</tr>
<tr>
<td>HSESTOCK</td>
<td>-0.3318</td>
<td>0.0825</td>
<td>-4.023</td>
<td>0.0002</td>
</tr>
<tr>
<td>SAVINGS</td>
<td>-0.0453</td>
<td>0.0053</td>
<td>-8.545</td>
<td>0.0000</td>
</tr>
<tr>
<td>UNEMPMT</td>
<td>49.939</td>
<td>16.763</td>
<td>2.979</td>
<td>0.0041</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>199.422</td>
<td>442.511</td>
<td>0.451</td>
<td>0.6538</td>
</tr>
</tbody>
</table>

Rho ($\rho$): $\rho_1 = 1.37506$; $\rho_2 = -0.74485$.
Standard error = 59.8328
Residual: DF = 62; Adjusted sum of squares = 230083.99; Residual variance = 3579.97.

The pattern of the autocorrelations of the residuals are shown in Figure 10.3. The plot indicates that the residuals for the current model is acceptable. A couple of the autocorrelations are marginally significant (lags 4 & 5), but generally the Box-Ljung statistics are not statistically significant at any lag. It is concluded that the residuals are random and the fitted model is adequate.

From the results shown in Table 10.5, the derived estimated demand function for residential building construction in Singapore, using an Autoregressive Non-linear Regression Algorithm, can be summarised as follows:

\[
\text{DEMAND} = 199.42 + 8.87 \times \text{BTPI} + 0.96 \times \text{GFCF} + 0.105 \times \text{HSELOAN} \\
+ 39.30 \times \text{POPULATN} - 0.33 \times \text{HSESTOCK} - 0.045 \times \text{SAVINGS} \\
+ 49.94 \times \text{UNEMPMT}
\]

With the elimination of the autocorrelations of the residuals, the statistical significance and the signs of the regression coefficient estimates would have been corrected to depict their true values. A close examination of these values reveals that multicollinearity may be present in this model. The
Autocorrelations: ERR_1 Error for DEMAND

<table>
<thead>
<tr>
<th>Lag</th>
<th>Corr.</th>
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<th>-.5</th>
<th>-.25</th>
<th>0</th>
<th>.25</th>
<th>.5</th>
<th>.75</th>
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<th>Box-Ljung Prob.</th>
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<td></td>
<td>2.107</td>
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<td>.042</td>
<td>.115</td>
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<td>4.317</td>
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<td></td>
<td></td>
<td></td>
<td>14.405</td>
</tr>
</tbody>
</table>

Plot Symbols: Autocorrelations * Two Standard Error Limits.

Total cases: 72 Computable first lags: 71

Figure 10.3 Autocorrelations of the residuals of the Second-order Autoregressive Non-linear Regression Model
statistical significance of the coefficient estimates for POPULATN and CONSTANT is found to be relatively high. However, this should not affect the forecasting performance of the model as a whole since a marked reduction in the standard error has been achieved. The standard error has decreased from 113.92 in the Multiple Linear Regression model to 59.83 in this model. The residual sum of squares has also reduced drastically, from a value of 830623 to a much lower value of 230084. In support of this view, Newbold and Bos (1990:29) stressed that "whilst estimators of the regression coefficients can be quite imprecise in the presence of serious multicollinearity, good forecasts may still result from the overall fitted model." The signs of the coefficient estimates remain the same as before.

10.5 Construction demand modelling and forecasting using Artificial Neural Networks

The main objective of this section is to apply a non-regression method to develop a construction demand model. It is also used to generate forecasts and their accuracy will be evaluated in Section 10.6 to determine the model's predictive ability.

The model is to be built using the ANN technique, a state-of-the-art Artificial Intelligence (AI) forecasting method. This technique is based on a pattern recognition and classification concept, having similarities with the structure and function of biological neurons. The ability to form non-linear mapping has made it successful in modelling and forecasting complex systems such as stock markets. The application of this technique to model residential building construction demand in Singapore is fully described below.

10.5.1. Application of the Backpropagation learning algorithm

Backpropagation is one of the most widely used learning, or training, algorithms. It is a supervised learning procedure which adopts the error-correction rule. It is capable of learning internal representations with the presentation of a set of input-output patterns, and can be applied to multi-layered neural networks with hidden layers and PEs using only internal computation. Based on the backward-error-propagation concept, two processing stages are involved when each input-output pattern is presented to the network. During the first stage, the input pattern is propagated forward to produce the actual output. This output is compared with the desired output to produce the error signal. The second stage involves a backward pass through the network, during which the error signal is transferred to each unit in the network. This backward propagation allows, firstly, recursive
computation of the error signal and, secondly, appropriate modification of the weights of the interconnections to allow learning to take place. Effectively, each adjustment of the weights proceeds in the direction of minimizing the mean sum of squared errors between the actual and desired outputs. These two stages are repeated for each new input-output pattern until an optimum set of weights is obtained. At this point, the network is trained and it should be able to give the "correct" output when presented with the associated inputs.

The first, and perhaps, the most important task in ANN modelling is determining an optimum network architecture. It is basically defined by the number of layers, the number of PEs in each layer and the general interconnection scheme. Often, the optimum is achieved by testing a few proposed designs, finally selecting the one that gives the best performance. The NeuroForecaster software automates this process with the use of a search and optimization technique called Genetic Algorithm (GA). GA (Goldberg, 1989) is a parallel, adaptive search algorithm also inspired by the mechanisms of biological evolution and has been used to solve a variety of optimization problems. The main idea of GA is to start with a population of solutions to a problem and then attempt to produce new generations of solutions which are better than the previous ones. There are four stages in the genetic search process: initialization, selection, crossover and mutation. In the initialization stage, a population of genetic structures which are randomly distributed in the solution space is selected as the starting point of the search. During the selection stage, each structure is evaluated using a set of user-defined criteria. The best structures are then selected for reproduction. The selected structures enter the third stage where they are combined using crossovers to allow existing structures to be further tested and also to introduce new structures into the population for evaluation. The final stage, mutation, functions as a background operator with a very low probability of application. It is used to alter one or more components of a selected structure, providing the means of introducing new information into the population.

In the case-study, designing of the ANN architecture is automated by combining the use of two adaptive processes: genetic search through the network architecture space, and Backpropagation learning in individual network to evaluate the selected architectures. The genetic process is depicted in Figure 10.4. It is a repetitive process where cycles of learning in individuals are nested within cycles of evolution in populations. Each individual ANN is attributed with a particular design configuration and, each learning cycle presents it with a set of input-output patterns. The Backpropagation learning algorithm then compares the network's actual output with the desired output and modifies its connection weights so that it performs the desired input-output mapping task more accurately. Each evolution cycle processes one population of network designs according to
their associated selection criteria, such as the training error computed during the learning cycles, to yield an offspring \textit{population} of more highly adapted network designs. In this case, only the best individual reproduces to yield the genotypes in the next generation, and the evolutionary process continues.

The automated design procedure derived a three-layered network architecture for the ANN model. It consists of an input layer with seven PEs, a hidden layer with five PEs, and an output layer with one PE. Figure 10.5 shows, graphically, the components of the network architecture of the ANN model. An average of 15,000 iterations were utilised to design and train the ANN model. A window size of 4 produced the best results when sizes 1, 2, and 4 were experimented. This is reflected by a much smoother learning trend during the various test cycles. The window size effectively defines the number of consecutive rows to be used together as one set of input patterns to train the model. In this case, a larger window size works better because it serves as a good way to capture temporal information contained in time-series data. For quarterly time-series data, a window size of 4 is often the most effective. A total of 64 \textit{chromosomes}, or hidden units, were utilised in the whole evolutionary process. The initial size of the \textit{population} of networks was three and the best network design was produced after an average of about 42 evolutionary cycles.

Although there are no rules governing the design of ANN architectures, an understanding of the function of the different layers helps to justify their specification. The input layer is used to present data patterns to the ANN. The size of the input layer, or the number of PEs in this layer, is usually determined by the number of input variables. In the case of this study, there are seven indicators used as input variables. The function of the hidden layer is to act as an abstraction field, pulling features from the inputs. On the one hand, increasing the number of sequential hidden layers augments the processing power of the ANN but, on the other, it significantly complicates training by intensifying the "black-box" effect where errors become more difficult to trace. In addition, more hidden layers require longer training time and more training cases in order for the network to learn properly. In view of this, most Backpropagation networks are designed to have one, or at most two, hidden layers. Specifying the size of the hidden layer is the most subjective aspect of network designing and, therefore, two guidelines have been developed. The first relates the number of hidden units to the number of training cases (NeuralWare, 1993), while the second associates it with the size of the input layer (Bailey and Thompson, 1990). Applying these guidelines to the case-study, the optimum number of hidden PEs is between two and five. The general idea is that too few hidden PEs render the mapping process insufficient while too many allow the network to memorize the training cases rather than extract the general features that will enable it to handle unseen cases. An optimum
Figure 10.4 The Genetic Algorithm Evolutionary Process
Figure 10.5 Components of the Artificial Neural Network Model Architecture

(Note: All the interconnections have not be shown)
size is required so as to achieve a balance between the need for accuracy and the ability to generalize. Finally, the output layer contains the output PEs. The size of this layer depends on the number of target variables specified in the study. Since construction demand is the only target variable in the case-study, the size of the output layer is one.

10.6 Forecasting results

The forecasting ability of the models developed using regression and non-regression methods is evaluated in this section. Firstly, forecasts based on the unseen data are generated from each of the four models. The difference between the actual and predicted values is then computed to derive the forecasting errors. Secondly, the forecasting accuracy of the models is compared by applying some relative measures dealing with percentage errors. The following is a mathematical description of these measures:

a) Percentage error (PE)

\[ PE_t = \frac{X_t - F_t}{X_t} \times 100\% \]

where, \( X_t \) is the actual value at period \( t \); and \( F_t \) is the forecast value at period \( t \).

b) Mean Percentage Error (MPE)

\[ MPE = \frac{1}{n} \sum_{i=1}^{n} PE_i \]

where, \( PE \) is percentage error; and \( n \) is the number of forecasts.
c) Mean Absolute Percentage Error (MAPE)

\[ MAPE = \frac{1}{n} \sum_{i=1}^{n} |PE_i| \]

where, PE is the percentage error; and
n is the number of forecasts.

The results of the forecasts generated by the Multiple Linear Regression model, the Multiple Log-linear Regression model and the Autoregressive Non-linear Regression Algorithm model are tabulated in Tables 10.6, 10.7 and 10.8, respectively.

Table 10.6 Result of the forecasts generated by the Multiple Linear Regression model

<table>
<thead>
<tr>
<th>Period</th>
<th>Actual (X)</th>
<th>Forecast (F)</th>
<th>Error (X - F)</th>
</tr>
</thead>
<tbody>
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<td>1993, 1 Qtr</td>
<td>1638.1</td>
<td>1742.8</td>
<td>-104.7</td>
</tr>
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<td>1993, 2 Qtr</td>
<td>1680.7</td>
<td>1830.0</td>
<td>-149.3</td>
</tr>
<tr>
<td>1993, 3 Qtr</td>
<td>1723.7</td>
<td>1885.3</td>
<td>-161.6</td>
</tr>
<tr>
<td>1993, 4 Qtr</td>
<td>1751.8</td>
<td>1590.4</td>
<td>+161.4</td>
</tr>
<tr>
<td>1994, 1 Qtr</td>
<td>1760.4</td>
<td>1998.6</td>
<td>-238.2</td>
</tr>
</tbody>
</table>

Table 10.7 Result of the forecasts generated by the Multiple Log-linear Regression model

<table>
<thead>
<tr>
<th>Period</th>
<th>Actual (X)</th>
<th>Forecast (F)</th>
<th>Error (X - F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993, 1 Qtr</td>
<td>1638.1</td>
<td>1696.9</td>
<td>-58.8</td>
</tr>
<tr>
<td>1993, 2 Qtr</td>
<td>1680.7</td>
<td>1752.0</td>
<td>-71.3</td>
</tr>
<tr>
<td>1993, 3 Qtr</td>
<td>1723.7</td>
<td>1768.6</td>
<td>-44.9</td>
</tr>
<tr>
<td>1993, 4 Qtr</td>
<td>1751.8</td>
<td>1448.8</td>
<td>+303.0</td>
</tr>
<tr>
<td>1994, 1 Qtr</td>
<td>1760.4</td>
<td>1830.5</td>
<td>-70.1</td>
</tr>
</tbody>
</table>
Table 10.8 Result of the forecasts generated by the Autoregressive Non-linear Regression Algorithm model

<table>
<thead>
<tr>
<th>Period</th>
<th>Actual (X)</th>
<th>Forecast (F)</th>
<th>Error (X - F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993, 1 Qtr</td>
<td>1638.1</td>
<td>1524.4</td>
<td>+ 113.7</td>
</tr>
<tr>
<td>1993, 2 Qtr</td>
<td>1680.7</td>
<td>1597.4</td>
<td>+ 83.3</td>
</tr>
<tr>
<td>1993, 3 Qtr</td>
<td>1723.7</td>
<td>1644.6</td>
<td>+ 79.1</td>
</tr>
<tr>
<td>1993, 4 Qtr</td>
<td>1751.8</td>
<td>1445.9</td>
<td>+ 305.9</td>
</tr>
<tr>
<td>1994, 1 Qtr</td>
<td>1760.4</td>
<td>1704.0</td>
<td>+ 56.4</td>
</tr>
</tbody>
</table>

In the study, the ANN model was trained and tested twice, each time using a different set of randomly selected initial weights for the interconnections. After each training, forecasts based on the unseen data were generated by the model. The two independent forecasts produced by the ANN model are tabulated in Table 10.9. Details of the forecasts are given in Appendix 2. The purpose of training and testing the model more than once is to ensure that internal validity has been achieved. This is reflected by the consistency in the forecasts produced. Independent forecasts showing large deviations between them often mean that the model is either insufficiently trained or over-trained. Only small deviations would indicate that the model has received optimum training and is able to generate accurate forecasts.

Table 10.9 Result of the forecasts generated by the ANN model

<table>
<thead>
<tr>
<th>Period</th>
<th>Actual (X)</th>
<th>Forecast 1 (F1)</th>
<th>Error 1 (X - F1)</th>
<th>Forecast 2 (F2)</th>
<th>Error 2 (X - F2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993, 1 Qtr</td>
<td>1638.1</td>
<td>1660.3</td>
<td>- 22.2</td>
<td>1653.6</td>
<td>- 15.5</td>
</tr>
<tr>
<td>1993, 2 Qtr</td>
<td>1680.7</td>
<td>1677.5</td>
<td>+ 3.2</td>
<td>1676.9</td>
<td>+ 3.8</td>
</tr>
<tr>
<td>1993, 3 Qtr</td>
<td>1723.7</td>
<td>1692.7</td>
<td>+ 31.0</td>
<td>1691.1</td>
<td>+ 32.6</td>
</tr>
<tr>
<td>1993, 4 Qtr</td>
<td>1751.8</td>
<td>1730.3</td>
<td>+ 21.5</td>
<td>1744.1</td>
<td>+ 7.7</td>
</tr>
<tr>
<td>1994, 1 Qtr</td>
<td>1760.4</td>
<td>1761.6</td>
<td>- 1.2</td>
<td>1774.9</td>
<td>- 14.5</td>
</tr>
</tbody>
</table>

To summarise and compare the predictive ability of the four models, Table 10.10 shows the computed values of the relative measures of accuracy of the different forecasting techniques.
Table 10.10 Relative measures of accuracy of different forecasting techniques

<table>
<thead>
<tr>
<th>Measures of accuracy (%)</th>
<th>Multiple Linear Reg.</th>
<th>Multiple Log-linear Reg.</th>
<th>Non-linear Reg. Algorithm</th>
<th>ANN (Forecast 1)</th>
<th>ANN (Forecast 2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE for 1Q, 93</td>
<td>-6.39</td>
<td>-3.59</td>
<td>+6.94</td>
<td>-1.36</td>
<td>-0.95</td>
</tr>
<tr>
<td>PE for 2Q, 93</td>
<td>-8.88</td>
<td>-4.24</td>
<td>+4.96</td>
<td>+0.19</td>
<td>+0.22</td>
</tr>
<tr>
<td>PE for 3Q, 93</td>
<td>-9.38</td>
<td>-2.60</td>
<td>+4.59</td>
<td>+1.80</td>
<td>+1.89</td>
</tr>
<tr>
<td>PE for 4Q, 93</td>
<td>+9.21</td>
<td>+17.30</td>
<td>+17.46</td>
<td>+1.23</td>
<td>+0.44</td>
</tr>
<tr>
<td>PE for 1Q, 94</td>
<td>-13.53</td>
<td>-3.98</td>
<td>+3.20</td>
<td>-0.07</td>
<td>-0.83</td>
</tr>
<tr>
<td>MPE</td>
<td>-5.79</td>
<td>+0.58</td>
<td>+7.43</td>
<td>+0.36</td>
<td>+0.15</td>
</tr>
<tr>
<td>MAPE</td>
<td>9.48</td>
<td>6.34</td>
<td>7.43</td>
<td>0.93</td>
<td>0.87</td>
</tr>
</tbody>
</table>

By examining the values of the MPE and the MAPE, the forecasting behaviour of each model is revealed. The MPE indicates whether a model has a greater tendency to over-forecast or under-forecast. In the case of the Multiple Linear Regression model, a negative MPE value obtained implies that the model tends to over-forecast. On the other hand, positive MPE values derived for the other three models imply that they have a general tendency to under-forecast. Among these models, the ANN model has the lowest MPE for both of its forecasts.

However, the MPE does not give the magnitude of the errors incurred by each model because it takes into consideration the signs of the errors, hence allowing the positive and negative errors to cancel each other out. In this respect, the MAPE is a more appropriate measure since it uses the absolute values of the errors where signs are ignored. Among the regression models, the Multiple Log-linear Regression model is found to have the lowest MAPE (6.34 per cent) while the Multiple Linear Regression model is found to have the highest (9.48 per cent). The Autoregressive Non-linear Regression Algorithm model has obtained a MAPE value in between, which is 7.43 per cent. The average MAPE of the three regression models is 7.75 per cent.

The ANN model obtained MAPEs of 0.93 per cent and 0.87 per cent for its two forecasts, giving an average of 0.90 per cent. The deviation between them is only 0.06 per cent, indicating that the ANN model has achieved internal validity.

The average MAPE computed for the ANN model and the regression models is 0.90 per cent and
7.75 per cent, respectively. From this, it can be implied that the accuracy of the ANN technique is about 8.6 times higher than the regression methods.

10.7 Summary and discussion of findings

Firstly, the findings have shown that the non-linear regression techniques have performed better than the linear regression technique. It can be used to imply that a non-linear relationship does exist between demand for construction and the variables used to model it. To further verify this implication, a scatterplot matrix is used to examine the relationships between demand and its respective indicators. Figure 10.6 shows the scatterplot matrix with a cell designated for each pair of variables. It is evident that all the cells display a non-linear relationship between any two variables. Focusing only on the cells in the top row of the two matrices, where demand is plotted against the respective indicators, it can be seen that it is impossible to ascribe a precise functional form to any of these non-linear patterns.

Secondly, the findings have revealed that the Multiple Log-linear technique has produced the best results compared to the other regression techniques. Traditionally, the log-linear specification has been found useful in modelling the relationships among business and economic time series. Perhaps, this finding can be used to substantiate the economic belief that it is often more plausible to view relationships in terms of proportional rather than absolute changes.

Thirdly, the findings have indicated that the ANN technique has performed outstandingly better than the regression techniques. This corresponds to the results obtained in an earlier study (Goh, 1996) where it was found that the MAPE of the ANN model is only about one fifth of the MAPE of the Multiple Regression model. This may be attributed to the inherent nature of ANN techniques which are designed to capture functional forms automatically, allowing the uncovering of hidden non-linear relationships between the modelling variables. The ability of ANNs to approximate arbitrarily well a large class of functions provides considerable flexibility in the general task of modelling. On the contrary, regression techniques require functional forms to be specified manually. Hence, the accuracy of such methods is largely dependent on the precision of such specifications.

Finally, the findings have also highlighted that among the non-linear techniques, ANN has outperformed regression. This clearly indicates the inability of regression techniques to model complex non-linear relationships such as those shown in Figure 10.6. Although the use of the log-
Figure 10.6 Scatterplot Matrices showing the Relationship between Demand and the respective Economic Indicators
linear transformation and the non-linear regression algorithm has improved upon the linear regression, these two non-linear regression methods still could not measure up to the ANN technique. Superiority of ANNs arises because of their flexibility to account for potentially complex non-linear relationships not easily captured by traditional approaches (Donaldson and Kamstra, 1996).

10.8 General discussion

Model specification has always been a problem in econometric modelling. In order to avoid encountering the problem of having to ascribe a functional form to complex non-linear relationships, the general research strategy has been to formulate a provisional model on the basis of economic theory, experience and intuition, and then locate suitable data and fit the model. Dougherty (1992) criticised this approach, explaining that the final version of the model would be satisfactory because its specification would have been skilfully massaged to fit the particular data set, not that it really corresponds to the true model. Besides, such judgemental interventions of the modeller would have introduced personal biasness, further undermining the validity of such models.

However, the use of regression techniques in econometrics allows causal analysis to be carried out to explain the relationships between dependent and independent variables. The coefficient estimates and the various established significance tests allow the extent of the relationships to be clearly defined. In contrast, ANN techniques lack this ability as they are not able to assess the relative importance of the input factors used by the model to arrive at its conclusion. The absence of this explanatory power in ANNs has traditionally classify them as "black boxes" whose complex inner workings somehow transform inputs into predicted outputs. Traditionally, they are not designed to exploit existing expertise; instead they serve as highly intensive computational machines, deriving their ability to forecast through a long learning process based on pre-defined sets of input-output values. Although recently, Garson (1991) has developed a simple and intuitive method for interpreting the interconnection weights in order to understand the impact various input PEs have on the output PE, the black-box image of ANNs is still prevalent.

Having evaluated the ability of several forecasting techniques, it seems apt to conclude that no one technique is globally superior, but rather each method is appropriate for certain individual situations (Makridakis et al., 1982). The main strength of regression techniques lies in their ability to develop causal models, where changes in the inputs will affect the output of the system in a predictable and explanatory way, assuming that the cause and effect relationship is constant. However, their
weakness falls on the dubious task of having to select an appropriate functional form to describe this causal relationship. The power of the ANN technique exists in its inherent ability to form non-linear mappings, allowing it to successfully model and forecast complex non-linear systems. A major limitation of ANNs is that they lack explanatory capabilities. They do not provide users with details of how they reason with data to arrive at a particular outcome. Hence, ANNs are not suitable for applications where explanation of reasoning is critical. Another advantage that general regression techniques have over ANNs is simplicity in application. The ANN technique is complex in theory and time-consuming in application, especially in terms of computer time. These are probably the two most important deterrents to the spread of its use. However, these problems are progressively easing as more powerful computers are being developed, reducing the amount of computing time required. In addition, more successful application of this technique is emerging in research, justifying its superiority both in theory and practice.

10.9 Chapter Summary

In this chapter, the performance of alternative forecasting methods in modelling and predicting construction demand has been examined and evaluated. The focus is on discovering the forecasting abilities of different regression techniques, both linear and non-linear, and compare them to non-regression approaches such as ANNs. The aim of this study is to assess, objectively, the levels of forecasting accuracy that can be achieved by regression models and, at the same time, to determine if non-regression models can improve upon such levels.

The Singapore residential sector has been chosen for the case-study. There is a need to forecast residential building construction demand in Singapore because of the increasing importance of this sector in terms of its major share of value of contracts awarded per year. The sector's fluctuating demand patterns have also accentuated the need to explore alternative forecasting approaches with the objective of identifying one that can produce more accurate demand forecasts.

The indicators selected in Chapter 6 were used in the case-study to model residential building construction demand in Singapore. They are namely, Building tender price index, Bank lending for housing, Population, Housing stock (additions), National savings, Gross fixed capital formation for residential buildings and Unemployment rate. Quarterly time-series data of these indicators, spanning between 1975 and 1994, were used. They were divided into two datasets. The first was used to build the models and the second to test the models. This was to ensure that the models would
be tested on an unseen dataset.

Three different regression techniques were applied in the first stage of the case-study. They are namely, the Multiple Linear Regression, the Multiple Log-linear Regression and the Autoregressive Non-linear Regression Algorithm. After each method has been applied, the derived model was tested for multicollinearity by verifying the statistical significance and the signs of the coefficient estimates. Slight problems of multicollinearity were detected but they did not affect the overall fitted models because either justification could be found, as in the case of unemployment, or a marked reduction in the standard error and the residual sum of squares could be achieved.

In the second stage, the ANN technique was used to serve as a non-regression approach. The model was developed based on a combination of the Genetic and the Backpropagation Algorithms. The GA is a search and optimization technique that is able to determine an optimum design for the network after assessing, simultaneously, a few proposed designs based on a set of user-defined criteria. The Backpropagation learning algorithm is used to train the individual network in order to evaluate the selected architectures. This procedure derived a three-layered network architecture for the ANN model. It comprises an input layer with seven PEs, a hidden layer with five PEs and an output layer with one PE. Theoretical justifications were given to support the feasibility of this ANN architecture.

The derived regression and ANN models were subsequently used to generate forecasts based on the unseen dataset. For each model, absolute and percentage errors of the forecasts were computed. The MPE and MAPE were the two essential relative measures used to evaluate the behaviour and accuracy of the forecasts. Among the four models, the MPE revealed that only the Multiple Linear Regression model has a tendency to over-forecast. The others have the tendency to under-forecast. The ANN model achieved the lowest MPE in both of its forecasts. In order to examine the magnitude of the forecasting errors, the MAPE is a more appropriate measure. Among the regression models, the Multiple Log-linear model was found to have the lowest MAPE, while the Multiple Linear model have the highest. The ANN model also achieved the lowest MAPE among all the models. Its internal validity was reflected by a negligible deviation between its two independent forecasts.

A summary of the findings was given and several inferences were made. Firstly, non-linear regression techniques were found to have performed better than the linear method. Secondly, the Multiple Log-linear technique has produced the best results among the regression techniques.
Thirdly, the ANN technique has performed outstandingly better than the regression techniques. Finally, among the non-linear techniques, ANN has outperformed regression.

In conclusion, several general issues were discussed to highlight the strengths and weaknesses of the alternative forecasting approaches examined in the case-study. The main strength of regression techniques lies in their ability to develop causal models with explanatory powers. Their weakness is in the need of having to define precisely a functional form that will fit the data. The power of the ANN technique is in its inherent ability to form non-linear mappings, allowing it to model and forecast complex non-linear systems successfully. A general lack of explanatory capabilities is a major limitation of ANNs. Although ANN techniques have not been as popular as regression methods owing to their complexity in theory and application, it was suggested that advancement in computer technology is fast becoming the key to these problems.
CHAPTER 11

CONCLUSIONS AND RECOMMENDATIONS

11.1 Introduction

The aim of this chapter is to validate the research hypotheses by summarising the findings of the study and drawing conclusions from them. The theoretical basis of the study has been outlined in the research premises. Any validation of the hypotheses would help to justify the need for this study of which the broad intention is to improve upon the current state of research in construction demand modelling and forecasting.

The research premises and hypotheses set out at the beginning of the study are reviewed in Section 11.2. Together, they provide a theoretical basis for the study, serving as vital guidelines throughout the research.

The findings of Chapters 5, 6, 7 and 10 are summarised in Section 11.3. It concerns the theoretical identification and statistical selection of significant economic indicators of construction demand, and the comparative study of the accuracy of different forecasting techniques.

Based on these findings, the research hypotheses are verified in Section 11.4. From here, implications and conclusions are gathered for a critical discussion in Section 11.5. It essentially summarises the discussions made progressively in the study.

Several limitations of the study are noted and discussed in Section 11.6. The areas highlighted are dealt with in Section 11.7 where recommendations for further research are made. They serve as useful suggestions in the future expansion on the scope of this study.

11.2 A review of the research premises and hypotheses

Three distinct problem areas in past construction demand modelling and forecasting have been identified at the beginning of the study. In short, they are related to the subjective choice of economic indicators and the restricted use of forecasting methods. Limitations in these areas have
led to past studies generating models that cannot provide good forecasts. In order to deal with these problems concurrently, the study has based its objectives upon four research premises. They are reiterated as follows:

1) There has been insufficient examination of all possible economic indicators for use in modelling demand for different types of building construction. This may be attributed to the absence of a systematic approach to the identification and selection of economic indicators which satisfy the economic significance and statistical adequacy criteria.

2) The scope of the forecasting methods used in the past for construction demand modelling has generally been limited to building linear regression models, that is, linearity is assumed at the outset for the relationship between the modelling variables. In cases where non-linearity was considered, only log-linear forms were used. Their improvements, if any, over the traditional linear form have not been investigated.

3) The scope of non-linear forecasting methods used in construction demand modelling has also generally been restricted to the regression approach. Considering the need of having to manually specify non-linear functional forms to fit the data, there may exist a risk of such methods not modelling the true relationship between the variables, but only the form which the model should take, as subjectively judged by the modeller. The inability of such models to generate good forecasts may be the result of a common failure to explore a non-regression approach such as the ANN technique, which is specially designed to cope with complex non-linear systems.

4) There has been little or no comparative study of different forecasting methods used to model demand for construction. This has resulted in the adoption of forecasting methods without having an objective view of their strengths and weaknesses, particularly their predictive abilities. This may eventually lead to forecasters of construction demand being without adequate assurance as to the fidelity of their forecasts.

With these premises clearly defined, the study sets out to validate three research hypotheses. They are outlined as follows:
1) Demand in the construction industry is significantly related to a wide range of economic measures such as national output, population and employment, government fiscal policies, national consumption, investment and savings, industry and commerce, balance of payments, money and interest rates, and prices and wages.

2) A non-linear model can forecast demand for construction more accurately than a linear model.

3) The ANN technique, a non-regression approach, can outperform the regression approach in predicting demand for construction.

11.3 Summary of research findings

The main focus of this section is to summarise the findings obtained in Chapters 5, 6, 7 and 10. They covered the theoretical identification and statistical selection of economic indicators, and the evaluation and comparison of alternative approaches of forecasting demand for construction. The other chapters served as literature-review chapters, providing essential background issues for theoretical discussion and critique. The following is a brief recapitulation of the contents of each chapter.

The first objective of the study is to establish an economic relationship between the construction industry and the national economy. This was carried out in Chapter 2 where several theoretical issues were discussed. Firstly, the nature of building cycles and their relationship with business cycles were examined: and secondly, the construction industry's role in the national economic system, macroeconomic policy, and economic development and growth were discussed at length in three separate sections. Departing from theory, the chapter concluded with a factual review of the intimate relationship between the construction industry and the national economy in Singapore, confirming the important role played by its construction industry in areas such as socio-economic development and overall economic growth.

Chapters 3 and 4 served as theoretical review chapters for the two main topics of the study, and they are, construction demand and economic indicators. The essential definitions were given, supplementing discussions on theoretical issues such as the nature of construction demand, and the
purpose and use of economic indicators. Quantitative aspects, such as the methods of measuring and interpreting construction demand and economic indicators, respectively, were also examined.

The main objective of Chapter 5 is, firstly, to carry out a literature review of the economic and social factors that affect the demand for different types of building construction, and secondly, identify the economic indicators that correspond to these factors. In effect, this process provided theoretical justification for the identified indicators, ensuring that they have economic significance. The economic indicators identified for residential, industrial and commercial building construction demand are listed in Table 11.1.

With a list of theoretically significant economic indicators, Chapter 6 proceeded with the selection of those indicators that can achieve statistical adequacy. Two variable selection procedures namely, Stepwise and Forward, were used. Different levels of statistical significance were applied to each procedure, allowing different subsets of indicators to be selected. The indicators selected by the Forward Selection procedure, using the lowest entry of significance level (0.50), are given in Table 11.2. It shows an exhaustive list of indicators, categorised by the general groups of economic measures, selected for each type of building construction demand.
Table 11.1 Economic indicators theoretically identified for different types of construction demand

<table>
<thead>
<tr>
<th>Type of construction demand</th>
<th>Theoretically identified economic indicators</th>
</tr>
</thead>
</table>
| Residential building        | 1) Real GDP  
|                            | 2) GDP per head  
|                            | 3) Productivity  
|                            | 4) Interest rate  
|                            | 5) Household formation  
|                            | 6) Population  
|                            | 7) Property price index  
|                            | 8) Disposable income  
|                            | 9) Wages and earnings  
|                            | 10) Unemployment  
|                            | 11) Housing stock (Additions)  
|                            | 12) Planning approval issued  
|                            | 13) Consumer price index  
|                            | 14) GDP deflators  
|                            | 15) Building tender price index  
|                            | 16) Building material price index  
|                            | 17) Money supply  
|                            | 18) National savings  
|                            | 19) Bank lending |
| Industrial building         | 1) Business conditions  
|                            | 2) Export of goods  
|                            | 3) Trade balance  
|                            | 4) Industrial and manufacturing production  
|                            | 5) Real GDP  
|                            | 6) GDP per head  
|                            | 7) Productivity  
|                            | 8) Exchange rate  
|                            | 9) Unit labour cost  
|                            | 10) Unit business cost  
|                            | 11) Export price index  
|                            | 12) Population  
|                            | 13) Cyclical or leading indicators  
|                            | 14) Government revenues  
|                            | 15) Business expectation (manufacturing orders)  
|                            | 16) Wholesale sales and orders  
|                            | 17) Capital expenditure intentions  
|                            | 18) Total investment  
|                            | 19) Money supply  
|                            | 20) National savings  
|                            | 21) Interest rate  
|                            | 22) Unemployment  
|                            | 23) GDP deflators  
| Commercial building         | 1) Real GDP  
|                            | 2) Unemployment  
|                            | 3) Leading indicators  
|                            | 4) GDP deflators  
|                            | 5) Commercial land values  
|                            | 6) Business conditions  
|                            | 7) Retail sales  
|                            | 8) Property rental values  
|                            | 9) Property price index  
|                            | 10) Tourist arrivals  
|                            | 11) Money supply  
|                            | 12) National savings  
|                            | 13) Interest rate  
|                            | 14) Planning approvals issued  
|                            | 15) Foreign investment  
|                            | 16) Population  
|                            | 17) GDP per head  
|                            | 18) Productivity  
|                            | 19) Employment  
|                            | 20) Fixed investment |

Footnote: The economic indicators are not ranked in any order of importance.
Table 11.2 Economic indicators statistically selected for different types of construction demand by general groups of economic measures

<table>
<thead>
<tr>
<th>General groups of economic measures</th>
<th>Residential building construction demand</th>
<th>Industrial building construction demand</th>
<th>Commercial building construction demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>National output</td>
<td>GDP per head; Productivity; and Real GDP.</td>
<td>Leading indicators; Productivity; and Real GDP.</td>
<td>Leading indicators; GDP per head; Productivity; and Real GDP.</td>
</tr>
<tr>
<td>Population and employment</td>
<td>Population; and Unemployment.</td>
<td>Population; and Unemployment.</td>
<td>Employment (commercial sector); and Unemployment.</td>
</tr>
<tr>
<td>Government fiscal policies</td>
<td></td>
<td>Government rates and fees.</td>
<td></td>
</tr>
<tr>
<td>National consumption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment and savings</td>
<td>Planning approvals issued; Housing stock; National savings; and GFCF.</td>
<td>Capital expenditure intentions; National savings; and Total investment in manufacturing.</td>
<td>Planning approvals issued; Foreign investment; and National savings.</td>
</tr>
<tr>
<td>Industry and commerce</td>
<td>Business conditions; Business expectations; Industrial and manufacturing production; and Wholesale sales.</td>
<td>Business conditions; Retail sales; and Tourist arrivals.</td>
<td>Business conditions; Retail sales; and Tourist arrivals.</td>
</tr>
<tr>
<td>Balance of payments</td>
<td></td>
<td>Exchange rate; Export of goods; and Trade balance.</td>
<td></td>
</tr>
<tr>
<td>Money and interest rates</td>
<td>Bank lendings; and Money supply.</td>
<td>Interest rate; and Money supply.</td>
<td>Interest rate; and Money supply.</td>
</tr>
<tr>
<td>Prices and wages</td>
<td>Building material price index; Building tender price index; Consumer price index; Wages and earnings; and Property price index.</td>
<td>GDP deflators; Export price index; Unit business cost; and Unit labour cost.</td>
<td>Property price index; Commercial land price; and Property rental price.</td>
</tr>
</tbody>
</table>

For the purpose of demand modelling, a smaller set of variables was preferred. This was to avoid the problems or lessen the effects of overfitting and multicollinearity. A smaller subset of indicators derived from the more stringent Stepwise Selection procedure using a higher entry level of significance (0.05 or 0.10) was chosen. The subset comprised seven indicators namely, Building tender price index, Bank lending (for housing), Population, Housing stock (additions), National savings, GFCF (for residential buildings) and Unemployment. These indicators were subsequently used in Chapter 10 to model residential building construction demand in Singapore.
The steps involved in the theoretical identification and statistical selection of economic indicators were integrated into a systematic approach in Chapter 7. The whole process was outlined in four distinct stages as follows:

**Stage One: Theoretical identification**

a) Examine characteristics and determinants of demand for construction;
b) Identify influencing economic and social factors;
c) Check their conformity with economic theory; and
d) Select economic indicators that represent each factor.

**Stage Two: Data collection and pre-processing**

a) Statistical re-classification of economic indicators;
b) Data collection from published sources; and
c) Apply data transformations such as, deflation, disaggregation and smoothing.

**Stage Three: Statistical selection**

a) Choose variable selection methods and appropriate levels of significance;
b) Apply chosen selection procedures;
c) Examine results of statistical selection; and
d) Attempt to justify unselected indicators.

**Stage Four: Usage**

a) Use unselected indicators whose statistical insignificance cannot be justified as additional modelling variables;
b) Use variables that have been selected by the more restrictive procedure to compile an exhaustive list of indicators that has met the economic significance and statistical adequacy criteria; and
c) Use variables that have been selected by the less restrictive procedure to model demand for construction.
A schematic representation (see Figure 7.1), in the form of a flowchart, was also provided to illustrate the various steps and stages of this systematic approach.

In order to proceed to the next stage of work, Chapters 8 and 9 introduced the two alternative approaches to forecasting that are of interest in this study. The Regression approach was covered in Chapter 8, providing a theoretical background and a review of some construction demand models that were built by this approach. This was followed by a critique of the prevailing methods used for construction demand modelling and forecasting. Two main conclusions were drawn: (1) there is a need to critically evaluate and compare different forecasting techniques; and (2) there is a need to explore more complex non-linear forms of modelling. As an alternative to the Regression approach, Chapter 9 offered an AI approach to forecasting. The chapter provided an overview of the ANNs technology, focusing on the concepts, constructs and terminology, and a description of some of the key paradigms and their applications.

The main objective of Chapter 10 is to examine the performance of different forecasting methods used to model and predict construction demand. Four techniques were applied in the case-study of the Singapore residential sector. They were, namely, the Multiple Linear Regression, the Multiple Log-linear Regression, the Autoregressive Non-linear Regression Algorithm and the ANN. The derived models are as follows:

1) The Multiple Linear Regression Model:

\[
\text{DEMAND} = -3127.54 + 3.81 \text{ (BTPI)} + 1.29 \text{ (GFCF)} + 0.11 \text{ (HSELOAN)} \\
+ 1525.87 \text{ (POPULATN)} - 0.52 \text{ (HSESTOCK)} - 0.06 \text{ (SAVINGS)} \\
+ 126.20 \text{ (UNEMPMT)}
\]

where, DEMAND is Demand for residential building construction; BTPI is Building tender price index; GFCF is Gross fixed capital formation; HSELOAN is Bank lendings (for housing); POPULATN is Population size; HSESTOCK is Housing stock (additions); SAVINGS is National savings; and UNEMPMT is Unemployment.
2) The Multiple Log-linear Regression Model:

\[
\begin{align*}
\log\text{DEMAND} &= 11.263 + 0.396 (\log\text{BTPI}) + 0.936 (\log\text{GFCF}) + 0.689 (\log\text{HSELOAN}) \\
& \quad + 1.843 (\log\text{POPULATN}) - 0.286 (\log\text{HSESTOCK}) \\
& \quad - 1.816 (\log\text{SAVINGS}) + 0.488 (\log\text{UNEMPMT}).
\end{align*}
\]

3) The Autoregressive Non-linear Regression Algorithm model:

\[
\begin{align*}
\text{DEMAND} &= 199.42 + 8.87 (\text{BTPI}) + 0.96 (\text{GFCF}) + 0.105 (\text{HSELOAN}) \\
& \quad + 39.30 (\text{POPULATN}) - 0.33 (\text{HSESTOCK}) - 0.045 (\text{SAVINGS}) \\
& \quad + 49.94 (\text{UNEMPMT}).
\end{align*}
\]

4) The ANN model:

The ANN model consisted of three layers; an input layer with seven PEs, a hidden layer with five PEs and an output layer with one PE (see Figure 10.5). Each PE in the input layer represented one of the seven economic indicators namely, Building tender price index, GFCF, Housing stock (additions), Bank lendings (for housing), National savings, Population and Unemployment. The PE in the output layer represented residential building construction demand. An average of 15,000 iterations were used to train the model, applying the Backpropagation algorithm for learning and the GA for optimizing the search of the best network.

The four models were used to generate forecasts over a period of five quarters, that is, from first quarter of 1993 to the first quarter of 1994. Data in this period had not been used in building the models, allowing the predictive ability of the models to be evaluated independently. Their forecasting performances were assessed based on the level of accuracy. Relative measures of accuracy were applied and the results of the comparative study are summarised in Table 11.3.
Table 11.3 A summary of the results of the comparative study of different forecasting techniques

<table>
<thead>
<tr>
<th>Types of forecasting techniques</th>
<th>Summary of relative measures of accuracy</th>
</tr>
</thead>
</table>
| Multiple Linear Regression               | MPE = -5.79  
|                                          | MAPE = 9.48  
|                                          | (1) Model tends to over-forecast; and  
|                                          | (2) Model has the highest MAPE; hence the most inaccurate.                   |
| Multiple Log-linear Regression           | MPE = +0.58  
|                                          | MAPE = 6.34  
|                                          | (1) Model tends to under-forecast; and  
|                                          | (2) Model has the third highest MAPE.                                        |
| Non-linear Regression Algorithm          | MPE = +7.43  
|                                          | MAPE = 7.43  
|                                          | (1) Model tends to under-forecast; and  
|                                          | (2) Model has the second highest MAPE.                                       |
| ANN                                      | MPE = +0.26 (average)  
|                                          | MAPE = 0.90 (average)  
|                                          | (1) Model tends to under-forecast; and  
|                                          | (2) Model has the lowest MAPE; hence the most accurate.                     |

11.4 Validation of research hypotheses

The three research hypotheses can be verified at this stage.

Firstly, it is apparent from Table 11.2 that all three types of demand for building construction namely, residential, industrial and commercial, are both theoretically and statistically related to many key economic indicators. Hence, it is reasonable to accept the first hypothesis of the study which states that:

"Demand in the construction industry is significantly related to a wide range of economic measures such as national output, population and employment, government fiscal policies,
national consumption, investment and savings, industry and commerce, balance of payments, money and interest rates, and prices and wages.

Secondly, it can be seen from Table 11.3 that all three non-linear models, namely, the Multiple Log-linear Regression, the Autoregressive Non-linear Regression and the ANN, have lower MAPE values than the linear model namely, the Multiple Linear Regression. This indicates that the non-linear models have produced more accurate forecasts than the linear model. Therefore, it is also reasonable to accept the second hypothesis which states that:

"A non-linear model can forecast demand for construction more accurately than a linear model."

Finally, among all the forecasting techniques shown in Table 11.3, the ANN has achieved the lowest MAPE. The outstanding forecasting ability of this non-regression technique validates the third hypothesis which states that:

"The ANN technique, a non-regression approach, can outperform the regression approach in predicting demand for construction."

11.5 Conclusions and discussion

Several conclusions can be drawn from this study. They are mainly summarised from Chapters 7 and 10.

Firstly, the study has proposed a systematic approach to the identification and selection of economic indicators to model demand for construction. The use of this approach would encourage a more thorough examination of the economic and social factors that influence construction demand. As a result, better explanatory and, or, predictive models can be built using more significant indicators after taking into consideration all possible ones. However, this is only feasible if the modeller plays a more active role, and has better knowledge of economic theory and alternative variable selection methods. Otherwise, the chances of deriving spurious models would be higher, especially when too many variables are used, causing problems such as multicollinearity and overfitting. Other potential problems include non-availability of data and increased amount of time required for data collection.
and modelling.

Secondly, the study has shown that for the regression approach, the non-linear techniques have performed better than the linear technique. It was implied that a non-linear relationship does exist between construction demand and its associated economic indicators. In fact, this was to be expected since it is quite unrealistic to assume that the complex nature of this relationship can be accurately described by the simple linear form.

Thirdly, the study has also shown that among the three techniques of the regression approach, the Multiple Log-linear has produced the best forecasting results. This finding was used to substantiate the economic belief that it is often more plausible to view relationships in terms of proportional rather than absolute changes.

Fourthly, it was revealed in the study that among the non-linear techniques applied, the ANN is the most accurate method. Although the use of non-linearity did help to improve the performance of the regression approach, superiority of the ANN technique is still apparent. It was explained that ANNs have the flexibility to account for potentially complex non-linear relationships not easily captured by traditional approaches.

Finally, between the regression and the non-regression approach, it was concluded that the latter has performed outstandingly better. Hence, the study has found that regression techniques which rely on manual functional-form specification are not as powerful as the ANN technique which is designed to capture functional forms automatically, allowing the uncovering of hidden non-linear relationships between the modelling variables.

Based on the statement by Makridakis et al. (1982) that no one technique is globally superior, but rather each method is appropriate for certain individual situations, the strengths and weaknesses of both the regression approach and the ANN technique were discussed. The main strength of the regression approach lies in its ability to develop causal models with explanatory powers. Its key weakness falls on the dubious task of having to identify a functional form which can best describe this causal relationship. On the contrary, ANNs are able to handle this task automatically as their powers lie in their inherent ability to form non-linear mappings, allowing them to model and forecast complex non-linear systems. However, their "black-box" characteristic means that they do not possess explanatory capabilities. Hence, ANNs are not suitable for applications where explanation
of reasoning is critical. Simplicity in theory and application is another advantage that the regression approach has over the ANN. ANN applications usually require more computer time and resources. But it was viewed that at the current rate of advancement in computer technology and AI research, the ANN technique is fast becoming popular, especially when more successful application is emerging in research.

11.6 Limitations of the study

Through the course of the study, several limitations have been noted and these are addressed here.

Firstly, the models were built without the consideration of any lagged relationships between construction demand and its indicators. This means that the current value of the dependent variable is assumed to be influenced only by the current values of the independent values. A potential weakness of such models is that they are static in character. It is often more plausible to allow the expected value of the dependent variable at the current time period to be influenced by the values taken by the independent variable at the current and all previous time periods. There is no reason to believe that one time period alone would exert the influence of all the past changes in an independent variable (Akintoye and Skitmore, 1994). Hence, with the use of lagged independent variables, a more dynamic relationship may be postulated. The main reason for not using lagged terms in the study is that it would cause a huge increase in the number of modelling variables. For instance, if four lagged periods were used for each of the seven indicators, each model would comprise a total of 35 independent variables. This number is considered too large, relative to the sample size of only 72 quarterly periods, causing a lost of too many degrees of freedom. Problems of overfitting and multicollinearity would also arise. All these factors may affect the reliability of the estimated parameters of the models. Therefore, in the case of this study, lagged terms can only be included when more sample data become available.

Secondly, the study has only examined one technique of the non-regression approach, that is, the ANN technique. Hence, it is difficult to generalise that the non-regression approach can outperform the regression approach in modelling construction demand based on only one technique. However, it was the interest in the ANN technique which initiated the idea of this study. Its many recent successes in economic and business forecasting applications had prompted this investigation into its potential usefulness in construction demand forecasting. Since ANNs are specifically designed
to handle complex non-linear problems without the need for any functional assumptions, it seems appropriate to compare them with regresional methods which rely primarily on a linear functional form. In this way, the approaches can be evaluated on two isolated criteria: non-linearity; and functional assumption. The prevalent use of the regression approach in construction demand modelling also warrants an assessment of its suitability against other forecasting techniques. Although the study is limited by the testing of only one non-regression technique, it is hoped that any positive finding would act as an impetus to future research in this area. The possibility of building more accurate demand models should be sufficient to encourage the consideration of other alternative methods.

Finally, it is apt to reiterate that although this is a case-study of Singapore, it has by no means undermined the aim of the study. The main objective is to examine the use of economic indicators and alternative forecasting approaches to model demand for construction. Hence, a cross-sectional comparison of different countries is not required. The in-depth study of a wide range of economic indicators and forecasting techniques for one country already entailed the collection and analysis of a massive amount of data. Case-studies of more countries would have complicated this process further, unless fewer indicators and techniques were to be considered. As the original intention is to explore all possible economic indicators and evaluate as many forecasting techniques as possible, it would seem more feasible and beneficial to focus the study on one country. The general approach developed in this study can then serve as a methodological framework and be applied in the context of other countries.

11.7 Recommendations for further study

Following the issues highlighted as limitations of the study, several recommendations for further study can be made.

The following are some additional multivariate forecasting techniques which may be considered for further study.

(1) There is a recent surge of interest in the State-Space forecasting approach. It combines the traditional regression and the Autoregressive Integrated Moving Average (ARIMA) time series methods into a unified framework to build a state-space model. In such a
system, the state of the process, referred to as the state vector, summarises all the information from the past that is necessary to predict the future. Once a model has been put in state-space form, the Kalman Filter may be applied. It is a recursive procedure for calculating the optimal estimator of the state vector given all the information that is currently available. A backward recursion, known as smoothing, enables optimal estimators of the state vector to be calculated at all points in time using the full sample. The main advantage of this approach is that it is an adaptive forecasting procedure. The model is dynamic as it is re-estimated, or updated, each time a forecast is made. A preliminary study of this approach had been undertaken by Merkies and Poot (1990) where they used state-space models to forecast non-residential building work in New Zealand. Ball and Wood (1994c) also investigated long-run international trends and volatility of housing investment using the Kalman Filter.

(2) The Box-Jenkins transfer functions referred to as multivariate Autoregressive-Moving Average (ARMA) models are a popular class of time-series models used to relate an output time series, which is to be forecast, to a set of related input variables. These dynamic models enable a time series to be forecast not only from its own past history but also from the past history of other related variables. It is an iterative approach involving four distinct stages: identification; estimation; diagnostic checking; and application (Box and Jenkins, 1976). The multivariate ARMA method is well-known for its high sophistication and inherent ability to produce parsimonious models. So far, only the univariate Box-Jenkins technique had been applied in a construction-related study (Oshobajo and Fellows, 1989).

Having established the ANN technique as the most accurate and, hence, the most suitable forecasting technique to model construction demand, an immediate extension of the study would be to develop ANN demand models for industrial and commercial buildings in Singapore as well. Their forecasting accuracy can be evaluated against the residential demand model to ascertain any consistency in performance. The methodological framework set up in this study can serve as useful guidelines for this task. On a broader basis, this can be extended to include other countries as well.

Finally, it is also recommended for further research that the proposition, which states:
"A systematic approach which allows more potential economic indicators to be considered increases the likelihood of building better construction demand models."

be verified. A suggested approach would be to build another residential demand model using randomly selected indicators, or those adopted by Akintoye and Skitmore (1994), and compare its forecasting accuracy with the models developed in this study. It will serve to test the concept of the proposed stage-by-stage approach.
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APPENDIX 1: Dataset used for modelling residential construction demand

<table>
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<th>Period (Qtr.)</th>
<th>Demand (sq.m.)</th>
<th>BTPI (90=100)</th>
<th>GFCF (S$m)</th>
<th>Hseloan (S$m)</th>
<th>Populatn (million)</th>
<th>Hsestock (sq.m.)</th>
<th>Savings (S$m)</th>
<th>Unempt (%)</th>
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APPENDIX 2 : Details of ANN model forecasts

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Title of paper: Residential Construction Demand Forecasting using Economic Indicators: A Comparative Study of Artificial Neural Networks and Multiple Regression.

Author: Goh Bee Hua


Publication details: Yr. 1996; vol. 14; pp. 25-34.

Abstract: In recent years, demand for residential construction has been growing rapidly in Singapore. This paper proposes the use of economic indicators to predict demand for residential construction in Singapore. At the same time, two forecasting techniques are applied, namely, Artificial Neural Networks (ANN) and Multiple Regression (MR), the former being a state-of-the-art technique while the latter a conventional one. A comparative study is carried out to determine whether the use of economic indicators with the application of the ANN technique can produce better predictions than with the MR method. A total of 12 economic indicators are identified as significantly related to demand for residential construction. Quarterly data from these 12 indicators are used to develop the ANN model. In order to assess the forecasting performance of this state-of-the-art technique, the same set of data is used to develop a conventional MR model. A comparison is made between the two models, in terms of their forecasting accuracy, by using a relative measure known as the Mean Absolute Percentage Error (MAPE). The forecasting error of the ANN model is found to be about one fifth of that derived from the MR model. The low MAPE values (less than 10 %) obtained for both the models also indicate that economic indicators may be used as reliable inputs for the modelling of residential construction demand in Singapore.