The Hong Kong Polytechnic University

The Department of Building and Real Estate

Forecasting Manpower Demand in the Construction Industry of Hong Kong

by

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

Wong Ming Wah James

ABSTRACT

Manpower is undoubtedly a valuable asset upon which the construction industry depends. Rapid changes of the economy, working arrangements, and technology in construction advocate reliable estimations of manpower demand to lessen future skills imbalance. Forecasting of the skill requirements appears to supply the means to an adequate resolution as there is no doubt that to facilitate human resources planning and budgeting, an organisation must precisely and in advance be able to determine the demand for personnel in each of the various disciplines. However, the reliability of the current construction manpower demand forecasts in Hong Kong has proved to be unsatisfactory. A solid understanding of future skill needs for the development of the industry is still lacking. The overall aim of this research is, therefore, to develop advanced manpower demand forecasting models, at both project level and industry level, to facilitate manpower planning for the construction industry of Hong Kong.

At the project level, statistical models for forecasting the demand of labour demand for a given type of construction project were developed using ***multiple regression analysis***. Details of 50 construction projects were analyzed to examine the relationships between the independent variables and the labour requirements. Forecasting models were developed to predict the demand for total labour and ten essential trades. Results reveal that project cost and project type play an important role in determining the project labour requirements. The

derived models were validated by various diagnostic tests and comparing the predicted values with the out-of-sample actual values of four projects. The forecasting models could serve as practical and advanced tools for both contractors and government departments to predict the labour requirements and number of jobs created at an early outset, thus enabling proper human resources planning and budgeting.

At the industry level, ***co-integration analysis*** was applied to develop a long-term relationship between aggregate manpower demand and the relevant variables in the construction industry. It was found that the aggregate manpower demand and the associated economic factors including construction output, wage, material price and interest rate are cointegrated. Subsequently, a ***vector error correction model*** incorporating short-run dynamics was developed for forecasting purposes. This model was then verified against various diagnostic statistical criteria. Upon completion of the aggregate model, occupational share manpower demand models were established by means of time series analyses at two levels: broad and detailed occupations. Using ***time series regression analysis***, forecasting models for the share of seven broad occupational groups were derived by incorporating variables including the time trend, changing mix of works and technology. The occupational share models of the professional and associate professional specific skill occupations were then developed using ***exponential smoothing/moving average techniques***. The construction output and labour productivity were found to be the most important and significant factors determining the quantity demand of construction manpower. Addressing these two attributes on policy formulation and implementation is critical to achieve a sustainable labour market.

This research provides a significant contribution in the area of manpower demand forecasting. The forecasting models developed in this study can benefit the construction industry by providing critical information on the future construction manpower requirements and assist policy makers and training planners to formulate training strategies. Apart from this practical use, the research also contributes new knowledge to the area of manpower forecasting and planning. It enriches and updates the understanding of advanced forecasting methodologies for collating and compiling construction manpower statistics so as to facilitate manpower planning at project and industry levels. The study also explores valuable perspective on the link between macro and microeconomic factors which affect the demand for construction personnel. The research framework and methodology developed in this study can be replicated in a variety of cities in Mainland China and other Asian countries. This will provide a solid framework for conducting comparative studies in this region.

PUBLICATIONS ARISING FROM THE THESIS

Journal Papers

1. Chan, A.P.C., Wong, J.M.W. and Chiang, Y.H. (2003) Modelling labour demand at project level – an empirical study in Hong Kong, *Journal of Engineering, Design and Technology*, 1(2), 135-50.

2. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2004) A critical review of forecasting models to predict manpower demand, *The Australian Journal of Construction Economics and Building*, 4(2), 43-56.

3. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2005) Time series forecasts of the construction labour market in Hong Kong: the Box-Jenkins approach, *Construction Management and Economics*, 23(9), 979-91.

4. Chan, A.P.C., Chiang, Y.H., Mak, S.W.K., Choy, L.H.T. and Wong, J.M.W. (2006) Forecasting the demand for construction skills in Hong Kong, *Construction Innovation*, 6(1), 3-19.

5. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2006) Time-series modelling of construction occupational demand: the case of Hong Kong, submitted to *Building and Environment*. *(IN PRESS)*

6. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H., Forecasting construction manpower demand: a vector error correction model, submitted to *Building and Environment*. *(UNDER REVIEW)*

7. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H., Forecasting construction labour demand: a multivariate analysis, submitted to *ASCE Journal of Construction Engineering and Management. (UNDER REVIEW)*

8. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H., The changing construction labour market: a case of Hong Kong, submitted to *Journal of Engineering, Design and Technology*. *(UNDER REVIEW)*

Conference Papers

1. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2003) Study of forecasting manpower demand and supply in the construction industry of Hong Kong. *In:* Newton, R., Bowden, A. and Betts, M. (eds.) *CIB W89 International Conference on Building Education and Research*, 9-11 April 2003, The University of Salford, 201-11.

2. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2003) Manpower forecasting in construction – identification of stakeholders' requirements. *In:* Anumba, C.J. (ed.) *The 2nd International Conference on Innovation in Architecture, Engineering and Construction*, 25-27 June 2003, Loughborough University. Centre for Innovative Construction Engineering (CICE), 301-14.

3. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2003) Determinants of construction manpower demand: a review from literature and practitioners' experience. *In:* Ahmed, S.M., Ahmad, I., Tang, S.L. and Azhar, S. (eds.). *The 2nd International Conference on Construction in the 21st Century*, 10-12 December 2003, The Hong Kong Polytechnic University and Florida International University, 158-63.

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5. Chan, K.K., Wong, J.M.W. and Chan, A.P.C. (2004) The effects of changing construction industry on surveying skill needs in Hong Kong. *In:* Wu *et al*. (eds.) *The 2nd CIB Student Chapters International Symposium*, 30-31 October 2004, Tsinghua University, 73-88.

6. Wong, J.M.W., Chan, A.P.C. and Chiang, Y.H. (2005) The quality of projections: manpower demand for the Hong Kong construction industry. *In:* Sidwell A.C. (ed.) *QUT Research Week International Conference*, 4-8 July 2005, Queensland University of Technology.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AA	Airport Authority
ADF	Augmented Dickey-Fuller Test
AIC	Akaike Information Criterion
ArchSD	Architectural Services Department
ARIMA	Autoregressive Integrated Moving Average
BD	Buildings Department
CAB	Construction Advisory Board
CCPI	Composite Consumer Price Index
CED	Civil Engineering Department
CEI	Capital to Employment Index
CIRC	Construction Industry Review Committee
CITA	Construction Industry Training Authority
CWDFC	Construction Workforce Development Forecasting Committee
C&SD	Census and Statistics Department
DEETYA	Department of Employment, Education, Training and Youth Affairs
DEWRSB	Department of Workplace Relations and Small Business
DfEE	Department for Education and Employment
DSD	Drainage Services Department
EMB	Education and Manpower Bureau
EMSD	Electrical and Mechanical Services Department
ES	Exponential Smoothing
ETWB	Environment, Transport and Works Bureau
FSB	Financial Services Bureau
GHS	General Household Survey
HD	Housing Department
HKAB	Hong Kong Association of Banks
HKCA	Hong Kong Construction Association
HKHS	Hong Kong Housing Society

HKMA	Hong Kong Monetary Authority
HRDC	Human Resource Development Council
HyD	Highways Department
IAB	Institute of Employment Research
ILO	International Labour Office
ISFOL	Institute for the Development of Workers' Vocational Training
KCRC	Kowloon-Canton Railway Corporation
LMA	Labour Market Analysis
MAPE	Mean Absolute Percentage Error
MLR	Multiple Linear Regression
MRP	Mediterranean Regional Project
MTRCL	Mass Transit Railway Corporation Limited
NHS	National Health Service
OECD	Organization for Economic Co-Operation and Development
OLS	Ordinary Least-Squares
OP	Occupation Permit
PCICB	Provisional Construction Industry Coordination Board
RMSE	Root Mean Square Error
ROA	Research Centre for Education on the Labour Market
RoR	Rate-of-Return
SBC	Schwartz Bayesian Criterion
SCDOT	The South Carolina Department of Transportation
TDD	Territory Development Department
VAR	Vector Autoregressive
VEC	Vector Error Correction
VTC	Vocational Training Council
WSD	Water Supplies Department

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

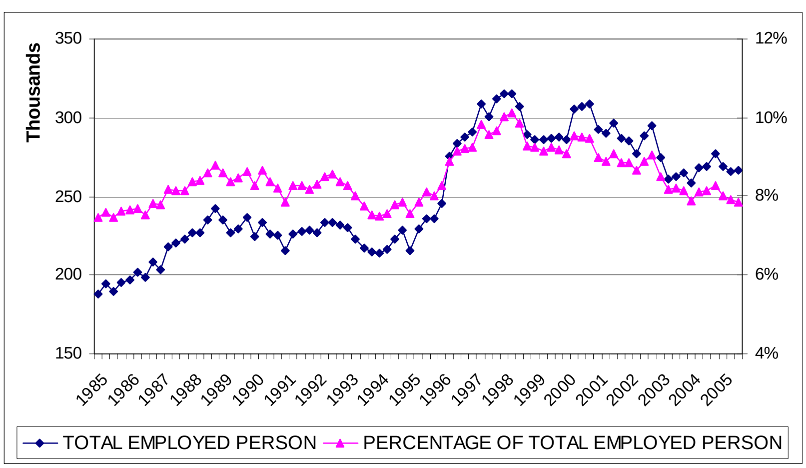
1.1 BACKGROUND

Since the early 1960s, manpower planning has become an important management tool for balancing and structuring the skills of the workforce (Gill, 1996). National planners were also increasingly aware that the competitiveness and growth of nation depended on the full exploitation of the skills of its people (Bartholomew, 1976). Ahamad and Blaug (1973) advocated that the interest in manpower forecasting in the past was derived from three different sources: (i) those interested in linking educational expansion to manpower requirements of a growing economy; (ii) those who realised that target-setting for GNP eventually entailed a translation of these targets into individual components; and (iii) those concerned with vocational counselling and placement services who considered that manpower forecasting can provide a rational basis for their activities. All these strands involve different considerations, but the common belief is that shortages and surpluses of manpower have to be controlled and minimised in all economies (Prasirtsuk, 1993).

The supply of manpower is principally governed by the existing stock of human resources trained over earlier years (Briscoe and Wilson, 1993). This stock changes through time as retirement, deaths and transfer to other industries serve to reduce the numbers available for employment (Agapiou *et al.*, 1995b; Huang *et al.*, 1996). It can be alleviated by skilled labour currently unemployed and also by those with the necessary skills, who can be attracted back into construction from other sectors of the economy (Chan *et al.*, 2002). More significantly, new trainees can be produced to increase the skill supply, although it takes a number of months or years to properly train a new skilled labourer. In this sense, the impact of education is not instantaneous, usually the necessary adjustments to labour supply lag behind changes in labour demand (Nekkers *et al.*, 2000). This process of training is bound to put pressure on matching labour supply and demand and may induce discrepancies within various labour market segments. One efficient way of minimising discrepancies is the use of active labour market policies. Taking into account the time-to-educate argument, such policies will be most effective when they are able to anticipate an expected future mismatch. This calls for an explicit forecasting approach.

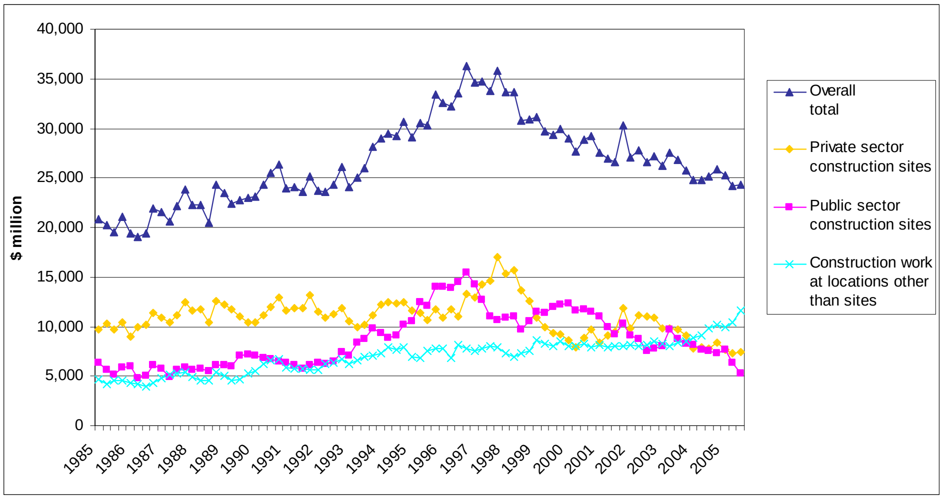
In construction, the pace of technological change, combined with increased specialisation especially on large-scale projects, will also focus more attention on the pattern of future skill requirements (Agapiou, 1996). It would be, in the long term, naïve to depend upon importation of labour and expansion of investment in the construction sector to solve skill shortages and surplus, respectively. Rather, planning of the skill training holds the key to resolve the demand and supply balance (Schmidt *et al.*, 2003). If employment forecasts were available to provide advanced warning of likely shortfalls, training providers would have the necessary indication to enable adjustments of skill supply and hence alleviate the damaging effects of resources mismatch (Agapiou *et al.*, 1995a).

In Hong Kong, the construction industry is important to her continued residential, commercial and infrastructural development. It influences the final flow of goods and services provided in the economy. The industry has made significant contributions to the economy, in terms of output and the share of the workforce involved (Rowlinson and Walker, 1995). Figure 1.1 reveals the trends of the total number of employed persons in the construction industry and the ratio of the active labour force over the past twenty years. The construction employment in Hong Kong has increased dramatically since 1985, reaching a peak of 315,100 in 1998 and fell to 257,400 in the 1st quarter of 2004 owing to the reduction in the construction workload and the downturn in the property market as indicated in Figure 1.2.



Source: General Household Survey, C&SD, HKSAR Government.

Figure 1.1 Total employed person in the Hong Kong construction industry (1985 – 2005)



Source: Report on the Quarter Survey of Construction Output, C&SD, HKSAR Government.

Notes:

- Private sector includes projects commissioned by private developers. Projects under the Private Sector Participation Scheme are also included.
- Public sector includes projects commissioned by the Government of the HKSAR, Mass Transit Railway Corporation, Kowloon-Canton Railway Corporation and Airport Authority. Projects under the Home Ownership Scheme commissioned by the Housing Authority are also included.
- Construction works at location other than site include decoration, repair and maintenance, and construction work at minor work locations such as site investigation, demolition, structural alteration and addition work, and special trades such as carpentry, electrical and mechanical fitting, plumbing and gas work.

Figure 1.2 Gross value of construction work at constant (2000) market prices performed by main contractors analysed by broad trade group (1985 – 2005)

Relative to most other sectors of the economy, construction output and the mix of construction works tend to be enormously fluctuated and the associated movements in skill demand can similarly be strong and rapid (Rosenfeld and Warszawski, 1993). During the Hong Kong construction boom in the mid 1990s, the construction industry experienced difficulties in recruiting site workers such as carpenters, masons, plumbers and steel benders (Ganesan *et al.*, 1996). In sharp contrast, the industry was severely hit by the recent recession and the downturn of the property market, resulting in grave surpluses of workforce in the labour market. Census and Statistics Department (C&SD) reported that the unemployment rate and underemployment rate in construction had a record high at over 17% and 13% respectively in the first quarter of 2004. These mismatches between labour demand and supply in the market have caused serious effects on the industry productivity and development in the industry.

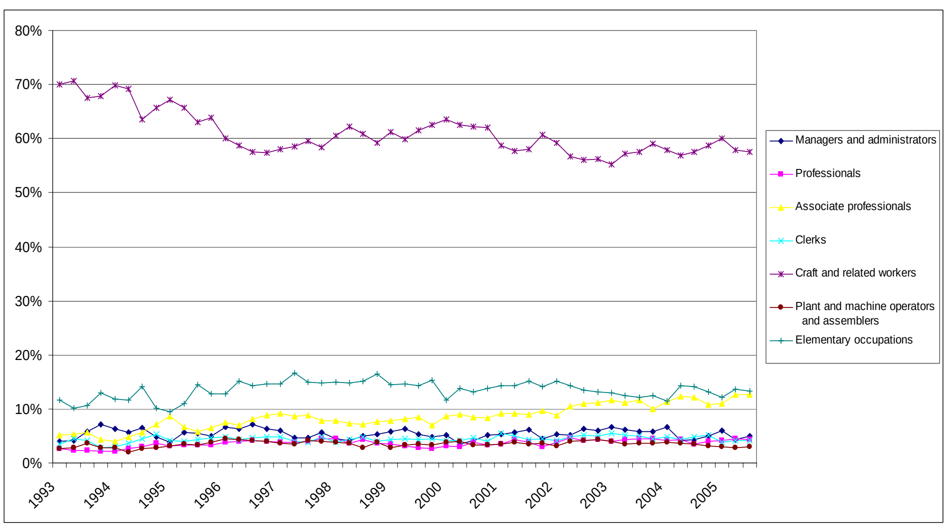
Recently the employment rate has rebounded slightly since the apparent increase of construction work in decoration, repair and maintenance, and the work at minor work locations. According to the latest figures from the Census and Statistics Department (C&SD), i.e. 3rd quarter 2005, the total number of employed persons in construction was 266,400 persons, representing 7.8% of the local employment level. The sub-totals of employed persons in construction by broad occupation in 2005 are shown in Table 1.1.

Broad Occupation	Number of Person	Percentage
Managers and administrators	13,200	4.95%
Professionals	11,300	4.24%
Associate professionals	33,800	12.69%
Craft and related workers	153,400	57.58%
Plant and machine operators and assemblers	7,900	2.97%
Clerks	11,100	4.17%
Elementary occupations	35,500	13.33%
Total	266,400	100.00%

Source: General Household Survey, C&SD, HKSAR Government.

Table 1.1 The number of employed persons in construction sector by broad occupation (3rd quarter 2005)

Figure 1.3 shows the trends of broad occupational demand for the period of 1993-2005 relative to national construction employment. Despite the pace of technology and automation implemented in the construction industry, the ratio of site operatives in the industry remains the majority of the total construction employment in 2005 (HKCSD, 2005). However, the share of craft and related workers as a whole declined steadily from 70.1% in 1993 to 57.6% in 2005. In contrast, the shares of higher-level non-manual occupations including managers, professional staff as well as technicians have exhibited noticeable growth over the past ten years. The demand for other broad occupations and has remained relative stable over the past decade. The reasons for these patterns are related to changes in technology, building methods, complexity of projects, number of establishments and the effect of regulations, which call for a higher demand on professional knowledge and management skills (Briscoe and Wilson, 1993; Ganesan *et al*., 1996).



Source: General Household Survey, C&SD, HKSAR Government.

Figure 1.3 Broad occupational shares (1993 – 2005)

These reflect the changing skill requirements in the construction industry of Hong Kong. Consequently, many of the challenges faced by the construction industry arise through a need to maintain a skilled and competitive work force (Rowings *et al.*, 1996). In the absence of effective manpower planning, the size of the local labour pool fluctuates, causing severe shortages and surpluses (Jayawardane and Gunawardena, 1998). An ideal manpower forecasting system that could take into account these changing requirements in a full behavioural model is critical to the sustainable development of the industry.

Although existing forecasting frameworks usually cover the whole of the labour market, analysis often focuses more strongly on identifying variations in wages, employment and the economy from changing supply-side forces, rather than from the demand perspective (Williams, 2004). However, rapid changes in the economy, working arrangements, and technology in the local context anxiously advocate the manpower demand forecasting, which focuses on the expected available job quantity and nature of the future requirements (Bartholomew *et al*., 1991). Osberg (1995) points out that demand-side data are critical in the explanation of labour market behaviour such as wage elasticity, variation in working hours, and unemployment levels. Neugart and Schömann (2002) also stress that a successful policy has to take into account the facts that education, training and lifelong learning policies must respond to shifts in the demand for skills and qualifications flexibly, and in due time. It is therefore crucial for the construction industry to appreciate the complexity of the labour resource requirements in order to sustain its skilled workforce.

At the site-level, the project-based nature of the construction process entails concerns about resources planning. In particular, ensuring adequacy of various construction staff and trades to make up project teams is a vital task (Druker and White, 1996). To assess staffing needs, an organisation must be able to determine the demand for personnel in each of the various disciplines precisely and in advance (Wong *et al.*, 2003a). However, skilled trades are difficult to be hired off the street, as demand arises. Indeed, a method of estimating a project's requirement for personnel can help the organisation of human resources planning, budgeting, and also facilitate each functional group to better plan its work (Persad *et al.*, 1995). As construction gets underway, it is imperative to estimate the volume of workers employed on site to ensure adequacy of site amenities and safety provision at the pre-construction stage (Uher and Loosemore, 2004). In addition, as is well documented, labour cost represents a significant portion of the final construction cost (Proverbs *et al.*, 1999), usually up to 40-60% for a building project (Buchan *et al.*, 1993). Therefore, it is critical of importance for construction companies and government departments to assess the manpower requirements in executing future projects.

At present, the existing manpower demand forecasts for the Hong Kong construction industry play an important role in the local strategic education and training planning for meeting future education and training. Nevertheless, without critically examining the determinants of the construction manpower demand and failure to predict the volume of construction work accurately, the reliability and applicability of these models are questionable (see section 3.4 for details). Hence, it is clear that a solid understanding of future skill needs for the development of the industry is still lacking.

In addition, although the Construction Industry Review Committee[1] Report (2001) has addressed the importance of a sound mechanism for projecting construction manpower supply and demand, lack of research still concerns manpower planning especially on methodology for compiling and exploiting manpower statistics to facilitate manpower forecasting, and to provide a reliable consistent basis for reference by policy-makers and the industry. The EMB (2000) and CIRC (2001) also highly recommend developing a detailed econometric model to produce short- to medium-term manpower forecasts in Hong Kong. To have a thorough understanding of the future labour market and to avoid structural unemployment or skill shortage, there is a genuine need to re-visit this very important concept of the demand for construction manpower. The above considerations provide the starting points for the present study.

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[1] In April 2000, the Construction Industry Review Committee (CIRC) was appointed by the Chief Executive of the Hong Kong SAR to comprehensively review the current state of the industry and to recommend improvement measures.

1.2 RESEARCH AIM AND OBJECTIVES

The aim of this research is to establish manpower demand forecasting models for the construction industry of Hong Kong. Such models would benefit the industry by identifying demand for specific skills and thereby facilitate manpower planning for the industry. The main objectives of the research are:

i) to critically review the previous and current manpower demand forecasting methods, both locally and overseas, as well as related studies in this area for the development of advanced manpower demand forecasting models;

ii) to identify the stakeholders' requirements of manpower forecasting models for the construction industry of Hong Kong;

iii) to make reference to the available literature and statistics, and to study various factors affecting the manpower demand for deriving a construction personnel manpower forecasting methodology;

iv) to develop, based on the methodologies developed above, practical forecasting models for estimating the construction occupational demand at project level and at industry level;

v) to assess the reliability and sensitivity of the models developed in order to allow subsequent calibration of the models to maintain its applicability.

1.3 SCOPE OF THIS STUDY

The practice of manpower forecasting embraces different levels: international, national, industrial, regional, project and firm level (Laslett, 1972). This research primarily focuses on the manpower demand forecasts at (i) project level; and (ii) industrial level locally i.e. manpower demand for a construction project and for the Hong Kong construction industry respectively. At the project level, owing to the limitation of data availability, this study covers the public capital works, and the capital works funded by the quasi-government bodies in the construction industry. The main concerns at project level are site workers engaged for building and civil engineering construction works prior to the issue of Occupation Permit (OP) or Completion Certificate or equivalent[2]. The trade classes of construction manpower are demarcated in line with the trade classification in the 'Monthly Return of Site Labour Deployment and Wage Rates in the Construction Industry' (Form GF527, in Appendix A) issued by the Environment, Transport and Works Bureau[3] (ETWB) of the HKSAR Government. Contractors involved in public works and public housing projects are required to submit this form to the Census and Statistics Department (C&SD) for reporting monthly return of site labour deployment and wage rates.

[2] Issuing Occupation Permit or Completion Certificate literally denotes that all relevant conditions the construction works have been completed and satisfied (Rowlinson and Walker, 1995).

[3] The ETWB is responsible for policy matters on environmental protection and conservation, development of transport infrastructure, provision of transport services, traffic management, public works, water supply, slope safety and flood prevention in Hong Kong.

At the industry level, the term “manpower” refers to the entire workforce engaged in the construction industry of Hong Kong. According to the definition given in the *General Household Survey* (GHS) issued by the C&SD, the industry includes building construction, civil engineering, plumbing, electrical wiring, air-conditioning installation and repair. Real estate personnel, architects and surveyors are excluded as they are categorised in the financing, insurance, real estate and business services industry. By occupation, the study covers seven broad categories of construction manpower, namely, Managers and Administrators, Professionals, Associate Professionals, Clerks, Craft and Related Workers, Plant and Machine Operators and Assemblers, and Elementary Occupations (Descriptions of these occupations are presented in Appendix B). Further detailed occupations are also investigated, the job descriptions for these occupations are recorded in the biennial manpower survey reports of the building and civil engineering industry issued by the Vocational Training Council (VTC).

1.4 RESEARCH FRAMEWORK

To achieve the objectives, this research is undertaken in three phases as presented in Figure 1.4. The research is conducted through both qualitative and quantitative approaches. It begins with a comprehensive literature review, which identifies gaps in the knowledge that formulated research objectives for this study. The recent forecasts generated for the local construction industry are also evaluated using an empirical analysis. In addition, previous forecasting models and factor affecting manpower demand are reviewed. Based on the literature search intended to provide the background of this research, phase two involves pilot study and data collection. Semi-structured interviews are conducted to identify the requirements of manpower forecasts in construction. The most appropriate forecasting method is thereby selected for modelling by comparing strengths and weaknesses of the contemporary forecasting approaches, the model requirements and the availability of the relevant data. A questionnaire is also designed to collect project details for developing a project-based forecasting model. Meanwhile relevant secondary data are acquired from various sources for industry-based modelling. Phase three focuses on the development of forecasting models to predict future manpower skill requirements, at both project and industry levels. The developed models are subsequently verified by various diagnostic tests and comparing the forecasts generated from the models with actual data. Details of research methodology are presented in Chapter Five.

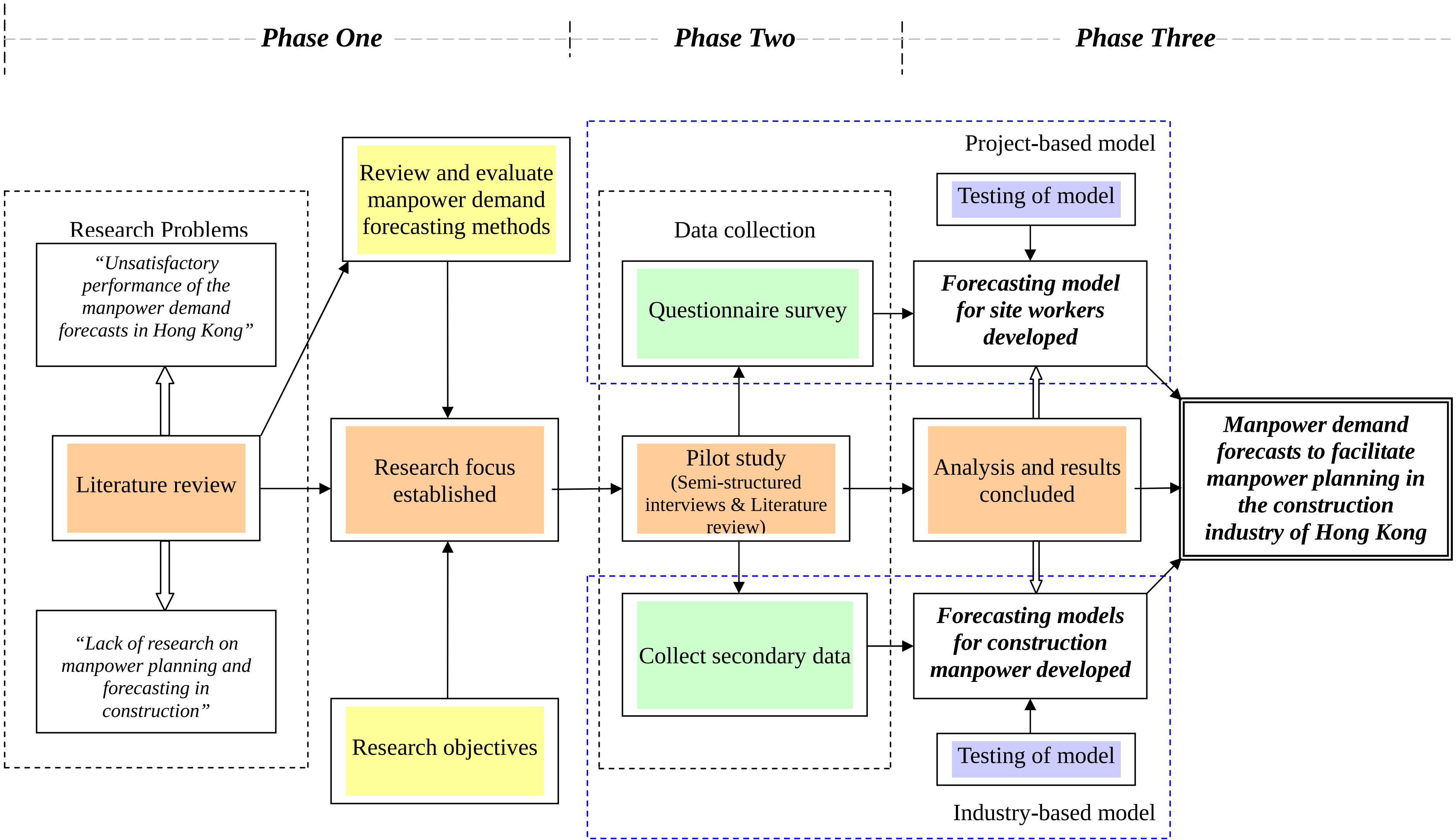


Figure 1.4 The research framework

1.5 SIGNIFICANCE OF THE RESEARCH

Labour resources are undoubtedly valuable assets upon which the construction industry depends (CIRC, 2001). Nurturing a quality workforce and promoting stable employment is often advocated as key components of industrial strategy. The field of manpower forecasting is becoming increasingly important where political and business practitioners have to swiftly respond to the changes in the labour market (Schmidt *et al.*, 2003). Government bureaux, training institutions and academies have been attempting to prevent or lessen future skills imbalance in the labour market. The field of forecasts of skills needs is essential in a world of work that is experiencing turbulent times.

This research provides a positive and significant contribution in the area of manpower demand forecasts. On the one hand, the project-based models could serve as a practical tool for government and construction organisations to estimate the quantity of manpower required for a construction project for the facilitation of human resource planning and budgeting at the initial construction stage. On the other hand, the industry-based forecasting models are useful to assess the future construction manpower requirements and assist policy makers in anticipating and adapting to business cycle-related fluctuations in this critical sector of the local economy, with the aim of adjusting and lessening future skills mismatches. Given the early identification of discrepancies between the demand and supply of the labour market, immediate action and long-term strategies can be launched by corresponding organisations and training institutions in order to meet the future education and training needs for the community. This is also consistent with the CIRC's recommendation on collation of construction manpower statistics for manpower planning.

The framework of this study offers the potential for gathering comprehensive information for the demand-side of the construction labour market. This analysis is an important area of manpower planning which has made significant contributions to human resource management (Kao and Lee, 1998). As this market is linked to other sectors of the Hong Kong economy, the model framework can illustrate how changes elsewhere in this economy make an impact on construction. The Government bureaux and training institutions can consider the recommendations of the research and decide the best approach with which to update Hong Kong's manpower forecasting practice, paying regard to the effectiveness and merits of the various suggestions and financial implications.

Apart from its practical use, the research can also contribute knowledge to the academic field as currently the area of manpower forecasting and planning is under-explored. It can also enhance the understanding of manpower forecast methodologies, requirements of manpower forecasts for construction and various labour economics issues in the construction market. Particularly, key factors affecting the requirements of the construction manpower are examined by empirical analysis. More importantly, robust manpower demand forecasting models are formulated based on advanced modelling techniques. This offers a valuable theoretical frontier for the field of manpower forecasting. In addition, research studies on forecasting manpower in construction have rarely been conducted in Asian countries. The results and the methodology adopted in this study are particular useful as a reference for Mainland China and other Asian countries.

1.6 STRUCTURE OF THE THESIS

This thesis contains eight chapters as summarised below.

Chapter One gives the introduction to the research study. It includes the background, research objectives and scope, and the significance of the research. The research framework and the structure of the thesis are also outlined within this chapter.

Chapter Two introduces the essential concepts of manpower planning and forecasting. The aims and importance of manpower planning are stated. The key requirements of the forecasting models are also identified. In addition, an overview of manpower planning development and the local and overseas manpower planning practice are given.

Chapter Three reviews various manpower demand forecasting models. The forecasting methodology, the outputs, strengths and limitations of these models are discussed. The local manpower demand forecasting models are evaluated based on the user requirements suggested together with empirical analysis. This attempts to seek options for improving the manpower forecasting techniques currently employed in Hong Kong.

Chapter Four identifies the determinants of manpower demand at the project and industry levels. Based on the review of manpower demand determinants, an assessment of relevant data sources is also given to serve as a vital basis for developing forecasting models.

Chapter Five presents the research methodology adopted in this research, including the research design and strategy, research process, data collection and the data analysis techniques adopted for developing the manpower demand forecasting models.

Chapter Six details the scope and development of the forecasting models of the manpower demand at the project level. Improvements to the existing model are highlighted. The principles of the model are delineated with the help of mathematical formulae. The applications and limitations of the model are discussed. It also attempts to verify the outputs of the forecasts generated by the models developed.

Chapter Seven presents the manpower demand forecasting models for the whole Hong Kong construction sector. Econometric method is used to produce a long-term relationship between construction manpower demand and relevant variables. The demand function is then reparameterised to an error-correction representation. The final restricted form of the model is tested against various diagnostic statistical criteria. The models for estimating occupational demand are then derived. The applications and limitations of the proposed demand model are also discussed.

Chapter Eight concludes the research and discusses the implications of the study. It combines the results of the earlier chapters to present a complete overview of the forecasting framework. Value and limitations of the research are highlighted. Recommendations are also made for future research related to the subject matter.

1.7 SUMMARY

A number of forecasting models have been developed since the 1960s that aim to predict future developments of the labour market and provide useful guidelines for achieving the desired development. However, research on forecasting manpower, especially for the construction industry, was rarely conducted in Hong Kong. Although several practical manpower forecasting models have been formulated in Hong Kong, the reliability and applicability of these models are questionable. This research aims to develop advanced models for forecasting manpower demand for the construction industry of Hong Kong in order to facilitate manpower planning.

This introductory chapter has provided the background of the work addressed in the study and the justification for conducting the study. Research objectives and scope are also stated. A research framework is put forward to facilitate this study.

In addition, a summary of the significance of the research is given together with the structure of the thesis.

CHAPTER 2 LITERATURE REVIEW – MANPOWER PLANNING AND FORECASTING IN THE CONSTRUCTION INDUSTRY

CHAPTER 2 LITERATURE REVIEW – MANPOWER PLANNING AND FORECASTING IN THE CONSTRUCTION INDUSTRY

2.1 INTRODUCTION

There is a widespread consensus among scholars and policymakers that investment in human capital produces benefits for firms, industries and societies (Agapiou, 1996). Better educated people have a higher probability of employment, are subject to a lower risk of unemployment, and receive, on average, higher income (OECD, 1998). However, some scholars acknowledge the hypothesis that technological progress, societal changes, and internationalisation of competition, capital and labour markets continue to evolve (Neugart and Schömann, 2002). This view challenges training and employment systems and the links between the two systems. Manpower planning was therefore implemented to serve as educational and vocational guidance to deal with the problems of growing unemployment, knowledge obsolescence and changing skill requirements (Heijke, 1993).

The primary objective of this chapter is to further explore the nature of manpower planning. All contributions focus on the following questions: (i) Why are manpower forecasts made? (ii) How important are manpower forecasts to the construction industry? and (iii) What are the users' requirements for manpower forecasting? Answers to these practical and essential questions are respectively presented in sections 2.2.1 to 2.2.3. In addition, the development of manpower planning and the contemporary manpower planning practices are reviewed in section 2.3. The knowledge of these aspects forms an important base for developing manpower forecasting models for this study.

2.2 THE MANPOWER PLANNING AND FORECASTING CONTEXT

2.2.1 Aims of manpower planning and forecasting

Lester (1966) advocates that the ultimate goal of manpower planning is to enlarge job opportunities and improve training and employment decisions, through calculated adjustment to the changing demand. More explicitly, Walker (1968) points out that the aim of manpower planning is '*…forecasting and planning for the right numbers and the right kinds of people at the right places and the right times to perform activities that will benefit both the organisation and the individual in it*'. In summary, manpower planning aims to ensure a smoother adjustment of supply to demand in occupational labour markets than would have been possible through reliance on the market mechanism alone.

Laslett (1972) describes the close relationship between manpower planning and forecasting as follows, '*A manpower plan is a structure for deciding what to do about some aspect of manpower such as education, training, and recruitment. A desirable and normal, but not inevitable, part of this plan is a forecasting or projection of the relevant factor*'. Therefore, manpower planning usually involves the forecasting of manpower demand and supply with various skills and qualifications, and assessment of the balance of these forecasts. These results then translate into action to bring manpower demand and supply into balance at a desirable level, such as educational training strategies (Castley, 1996a). However, Smith (1971) expresses that manpower plans can never be blueprints, or even goals in any rigid sense. They should be treated as one among many pieces of information which planners need to assess before taking decisions and then used to help evaluate the risks which exist in the present circumstances (Holden *et al*., 1990).

Hughes (1991) notes that there has been a general transformation regarding the objective of manpower planning since the 1960s due to previous criticisms of both the methodology itself and the aim behind the manpower forecasts. As highlighted by Colclough (1990), three major criticisms are levelled at these early national manpower forecasts:

i) National level employment planning was unnecessary since labour markets adjust to imbalances of their own accord, as in the neo-classical model, to ensure that the correct skills are produced;

ii) The forecasting approach was inflexible and invalid since it ignores the substitution process on the labour market between sectors and occupations;

iii) Inaccuracies in the underlying assumptions for forecasting will be compounded thus making the projections of little value.

Employment planners, however, refuted these criticisms. With regard to the first criticism, they point to evidence of market failure and to the long-lags in training which can lead to long-lasting imbalances in occupational labour markets. Secondly, it was highlighted that empirical evidence of the substitution elasticity for skills is low and argue that wage structures tend to exhibit stability over the long-term. Nevertheless, Freeman (1980) and, Borghans and Heijke (1996) showed how these substitutions can be implemented in a manpower planning model. The third criticism was rejected based on the grounds that the problem of forecasting inaccuracy is not unique to manpower forecasting but applies to any economic projections.

Consequently, policy makers still find employment forecasts useful and valuable (Wong *et al*., 2004). The main objectives of recent manpower forecasting, however, were adjusted and emphasized as follows:

i) to identify the implications of existing occupational trends;

ii) to provide information for policy makers on the changes likely to occur in the occupational profile of the labour force, and on the broad implications of these changes for educational, training and employment policies;

iii) to evaluate the effects of different policies on the level and structure of employment in the future;

iv) to provide information which facilitates career choices for society in general.

(Hughes, 1991)

These objectives contrast somewhat with the original uses of manpower planning which involved merely trying to pinpoint imbalances in occupational labour markets for periods far into the future. This implies that the manpower forecasts should be used as an input into medium-term strategy for the future decision makers in government, education and training, business, trade unions and individuals in the markets. If it is capable of providing reliable labour market forecasts, the functioning of the labour market may improve in the sense of better matches and faster adjustments to structural changes (Neugart and Schömann, 2002).

2.2.2 Importance of manpower planning and forecasting

In general the labour market is not flexible in its operation (Ahamad and Blang, 1973). Many separate submarkets are differentiated by occupations, and these submarkets are seldom in equilibrium. The existing disequilibria on the labour market are only gradually corrected, and are seldom fully eliminated, often attributed to lack of flexibility in wage structures, limited possibilities for substitution between submarkets and the high adjustment costs (Heijke, 1994). Instead of the frequent fire-fighting role performed by policymakers, manpower planning enables a more strategic approach to identifying and subsequently solving this problem. Identification of skill imbalances is the most important benefit to be gained from a systematic manpower planning exercise (Bennison and Casson, 1984). In this way forecasts may help reduce adjustment costs arising from imbalances on the labour and product market.

Agapiou (1996) also stresses that appropriate training can only be developed if training needs are carefully identified. If employment forecasts had been available to provide information to forewarn likely shortfalls, then training providers might have been able to boost the supply of skills and thereby mitigate some damaging effects of shortages (Mohamed and Srinavin, 2005). Manpower forecasting allows us to gain from advance 'knowledge' or to avoid disasters by virtue of predicting their occurrence. Such forecasts can then be used as guidelines for active labour market policies in the fields of training, job replacement and job creation (Hughes, 1991; Heijke, 1993). O'Connell and McGinnity (2002) also point out that keeping an eye on the demand side of the market while training people can improve the effectiveness of programmes. If they are sufficiently accurate, forecasts on labour market developments may contribute to a reduction in uncertainties about the return to education (Neugart and Schömann, 2002).

In particular, the construction industry places heavy reliance upon the skills of its workforce (Chiang *et al.*, 2004; CIRC, 2001). It is in a period of globalisation and rapid culture change accompanied by the introduction of new technologies and new ways of organising construction activities. Powerful national and multinational clients will continue to influence the choice of these technologies through their demands for faster construction times (Agapiou, 1996). The construction industry is thus anticipated to face increased competition in search of eligible recruits to train to match these skills. Hence, there is a need to assist interested parties in the construction industry to realise the importance of labour resources issues and the need for long-term planning of labour resource requirements, allowing them to train and retrain human resources to address the predicted skill imbalances.

In addition, researchers reveal that the fluctuations in construction output tend to be enormously varied and the movements in skill demand can similarly be strong and rapid (Rosenfeld and Warsazwski, 1993). Manpower forecasting can help anticipate and respond swiftly to changing requirements in occupational labour markets, otherwise structural unemployment or skill shortage impedes industrial development (Wong *et al*., 2004). Particularly, the construction industry contains a large number of quite distinct occupations or skill categories. A balanced workforce can also minimise any sudden surge in labour wages and hence construction cost (Ball and Wood, 1995). Additionally, Briscoe and Wilson (1993) proclaim that the projections provide planning data not only for field training but also for financial budgeting, through the estimated numbers contributing to training board levy income and grant expenditure. Hence, it is critical to prevent the non-completion of construction programmes and the damage to the economy caused by attempting to undertake construction, for which the resources are not available (Hillebrandt and Meikle, 1985).

2.2.3 Key requirements of manpower forecasting in construction

Although manpower forecasting is imperative to the development of any economy, the requirements of manpower forecasting have not been clearly identified (Wong *et al*., 2003a). A wide range of literature review and a series of semi-structured interviews were undertaken for this purpose (details of the interviews are presented in section 5.3.2). In particular, the review and consultation aim to gain a fuller understanding of the existing arrangements for manpower forecasting, and to identify potential end-users' requirements of manpower forecasts for the construction industry of Hong Kong. Set out below is an abbreviated list of the suggested requirements, categorised by (i) 'scope and contents of manpower forecasts' and (ii) 'process of producing forecasts' as presented in Figure 2.1.

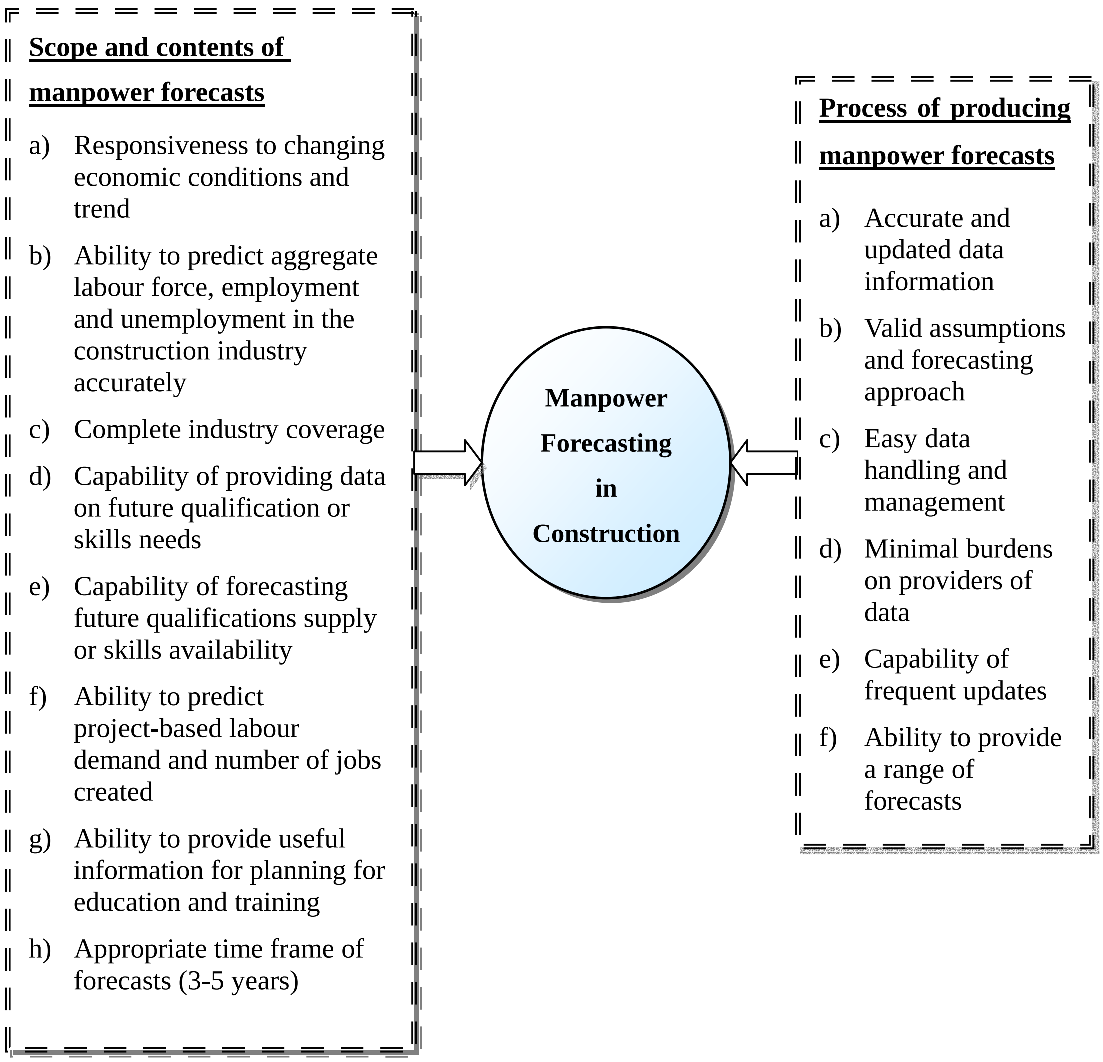


Figure 2.1 Key requirements of manpower forecasting in construction

A detailed report of the requirements is presented in Wong *et al* (2003a). These suggested requirements are useful to develop the framework of construction manpower forecasting models for this study. More importantly, it serves as a benchmark for future research to study and evaluate the capability of a manpower forecasting model for the industry.

2.3 AN OVERVIEW OF MANPOWER PLANNING PRACTICES

This section provides an overview of worldwide manpower planning practices. The origin and development of manpower planning are first introduced, followed by the contemporary manpower planning practices. The details of manpower forecasting systems in Hong Kong are then discussed.

2.3.1 Historical overview of manpower planning

Since World War II there has been a growing awareness that human capital endowments are important factors in economic growth, in addition to physical capital (Willems, 1996). Schultz (1961) and Becker (1962) were two of the first economists to state that education and training are important factors in improving productivity. The central theme of their human capital theory is that individuals can improve their productivity by investing in education and training. At a macro level this means that a country's domestic product can be enlarged by raising the educational level of the labour force, as long as the benefits are greater than the costs (Becker, 1975). This has led to the development of educational or manpower planning becoming prominent at the national level (Briscoe and Wilson, 1993).

Since then economists and educational planners have attempted to advise governments to avoid imbalances of skills. It was anticipated that employment plans developed could be used to guide policy decisions relating to the provision of educational and training programmes at a detailed level. One of the first manpower planning projects was the Mediterranean Regional Project (MRP) developed by the Bureau of Labor Statistics in the United States in the 1950s, and adapted for use in the Organization for Economic Co-operation and Development (OECD) in the early 1960s (OECD, 1965). The main objective of this project was to outline the educational requirements for the next fifteen years so as to reach specific targets for economic growth (Parnes, 1962). Thus the project did not primarily intend to forecast the future behaviour of demand and supply on the labour market, but rather to determine the labour supply required to achieve economic targets expressed in terms of economic growth or gross domestic product (Tinbergen and Bos, 1965). The project has been carried out in six Mediterranean countries including Greece, Italy, Portugal, Spain, Turkey and Yugoslavia.

Within the MRP, the 'manpower requirements approach' was developed for manpower planning. The rationale of this approach links the manpower requirements to the output of the industry and to developments in the rest of the economy, i.e. given economic targets, the growth of a certain industry will lead to proportional growths in the demand for each occupation within the industry

(Uwakweh and Maloney, 1991). The demand was then compared with the supply to determine the training needs (Willems, 1998). Parnes (1962) identified the following eight steps in the manpower requirements approach:

i) List the numbers of workers by sector of industry, occupation and educational class for the base year;
ii) Forecast the size of the total labour force, or in other words the total supply of manpower, in the target year by applying corresponding participation rate to population projection;
iii) Forecast the total employment by sector of industry in the target year, which consists of combining the economic targets for the gross domestic product, broken down by major sector, and a projection of labour productivity;
iv) Allocate this employment by industry among the different occupational classes based on past trends, aggregate over the sectors of industry to obtain the forecast of employment by occupation;
v) Forecast the requirements by educational type by converting the forecast of the occupational structure of employment;
vi) Estimate the future labour supply by type of education;
vii) Compute the differences between the forecast of labour demand and supply, the required change in annual outflow from the several types of education distinguished is then predicted, given the results of steps (vi) and (vii);
viii) Compute the required enrolments in each type of education to achieve the result of step (vii).

Following the MRP, several other research projects were initiated on the basis of its forecasting approach in a number of developed and developing countries (Ahamad and Blaug, 1973). Comprehensive national manpower forecasts for France, Canada, and West Germany were made during the 1960s while those for the United Kingdom and the Netherlands were not made until the 1970s and the 1980s respectively. However, the forecasting strategies adopted in practice have been widely criticised as described in the previous section. The OECD reported by Hollister (1967) represents a first complete evaluation of the manpower requirements approach in general and the MRP in particular. Other evaluation studies have been put together by Blaug (1967), Ahamad and Blaug (1973), Smith and Bartholomew (1988), Youdi and Hinchcliffe (1985) and Colclough (1990).

Despite these early disappointments and the criticisms, such defects did not lessen the need for some degree of planning of the labour market to ensure efficiency and equity (Castley, 1996b). Governments and policy makers retained an interest in manpower forecasting issues, in a less mechanistic and indicative fashion (Briscoe and Wilson, 1993). As a consequence, the providers of these have responded to the critics by adjusting the approaches taken. The new role of manpower planning and forecasting is to improve the functioning of the labour market by providing trends and development of labour markets in the near future (Willems, 1996). There was also a switch of focus away from educational planning to the provision of more general strategic guidelines, taking account of evidence that the relationship between occupation and qualification levels and type is the weakest link in the chain of educational forecasts (Hughes, 1994).

Besides the MRP-type planning strategy, many other approaches have also been adopted for educational planning. For example, Rate-of-Return (RoR) approach (Blaug, 1967), the Tinbergen model (Tinbergen and Bos, 1965), labour-output and density ratio approach, social-demand models (HMSO, 1963), linear-programming models (Psacharopoulos, 1979; Bowles, 1969) and surveys of labour market. However, these methods are unsuitable for making comprehensive occupational manpower forecasts either because of inaccurate forecasts or implausible assumptions (Hughes, 1991). Wong *et al*. (2004) and Hopkins (2002) conclude that the manpower requirements approach is still the dominant methodology to forecast occupational manpower demand for most countries.

In recent times, rather than relying exclusively on sophisticated long-term forecasts, workforce planners increasingly have used labour market analysis (LMA) for short-term assessment of training needs. The LMA is based on the 'market signals' such as enrolment data and relative wages to identify job opportunities and skill requirements (Campbell, 1997). This qualitative approach focuses on education qualifications by measuring pressure on the economic returns on investment in training (Middleton *et al*., 1993).

2.3.2 Contemporary manpower planning practices

Currently labour market forecasts differentiated by occupation are being created in many developed and developing countries (Van Eijs, 1994). Table 2.1 provides a comparison of the latest national planning practices adopted in eight developed countries, which have a fairly long history of manpower planning. These manpower planning practices are compared based on the attributes suggested by Neugart and Schömann (2002) including time horizon, interval for updates, degree of forecast disaggregation, data sources, organisations involved in the forecasting, forecasting approaches. This review helps identify best-practice in terms of manpower planning approaches and features of use and implementation of structures.

In most categories, the models applied in these selected countries have common features. For instance, the majority of countries use a time horizon of between five and ten years in the forecasts. The mutual aim of these forecasts is directed towards medium-term structural changes so as to provide an insight into the current and future positions of the various occupational and educational categories. In addition, with the aim to overcome the time-lag problem related to the availability of official data and to assess the impact of short-term developments, several countries including the Netherlands, the UK and the USA have opted for an annual or biennial update of the forecasts. Others countries in the comparison have still produced updates every five years, taking the risk of using obsolete information and forecasts in public policy debates on economic, structural and occupational change.

Country	Australia	Canada	Germany	Hong Kong
Time horizon	1998 – 2010	2000 – 2004	1999 – 2010	2000 – 2005
Interval for updates	5 years	5 years	5 years	5 years
Degree of disaggregation	113 industries and 340 occupations	139 occupations and 5 broad categories	By sector, job activities (33 nos.) and qualification	41 industry groups, 9 broad occupations, 5 educational levels
Major data sources	Forecasts by specialists; Census and labour force survey	Census, monthly labour force survey	Labour force survey, national accounts, social security records	General Household Survey; census data
Who pays for the forecasts?	The Department of Employment, Education, Training and Youth Affairs (DEETYA)	Labour Ministry (HRDC)	Federal and regional governments	Education and Manpower Bureau (EMB)
Who does the forecasts?	Independent research institute - Centre of Policy Studies, Monash University	Independent research institutes; federal forecasts are supplemented by regional and sectoral forecasts	Independent research institutes and federal research institutes (IAB)	Census and Statistics Department, EMB and Labour Department
Who uses the forecast?	DEETYA and the Department of Workplace Relations and Small Business (DEWRSB); state employment and training departments	Federal government for training programmes; sector councils to assess training needs, develop curricula & occupational standards and evaluate effectiveness of training efforts; career counselors and individuals	Mostly for government use	Mostly for government internal consumption
Demand-side forecasting approach	Industrial output and employment are derived using MONASH macro-econometric model. Employment by occupation in each state and territory are estimated using state-specific occupational shares from survey data. Share effects are extrapolated from historical trends and technological change.	Industrial output and employment are derived using COPS macro-econometric model. The industry employment then disaggregated into occupational categories through coefficient matrix developed by regression model. Sum of expansion demand and replacement demand produces estimates of job openings.	Using SYSIFO econometric estimates, the sectoral demand for labour is derived. Experts' assessments are used to supplement the estimates. Projected occupational employment was made by considering sectoral effect and technological and socio-economic changes. FreQueNz network was developed to identify skill requirements.	Projections were produced using extrapolation based on historical employment data. The projected growth rates are then examined and refined upon the views of experts. Applying these rates gives the projection of manpower demand by economic sector. The demand by occupation are projected on the basis of their past growth trends.
Supply-side forecasting approach	Based on changes of population and demographic structure; immigration levels; and changes in labour force participation	The total supply by occupation is equal to the previous stock by occupation plus the net number of new entrants.	Labour force accounts containing stocks and flows in the labour markets are used as the basis for forecasting.	Applying projected labour force participation rates to the population projection gives the manpower supply projection.
Implementation	DEETYA: Policy simulation, state employment and training departments	Federal Labour Ministry, Provincial Ministries of Education or Labour Ministries	Differences in the implementation between regions; no close links for the use of regional and national forecasts	Education and Manpower Bureau for making educational policies
Other feature(s)	Mobility across occupation was assumed according to historical patterns	Widespread use of forecasts; hardcover and Internet version; CD-ROMs are distributed to schools	Limited transparency and accessibility. A lot of qualitative information is used in estimation.	No explicit modelling of behavioural relationships and/or the wider economy.
Reference(s)	Adams *et al*. (1999); Adams & Meagher (1997)	Foot (1980); Smith (2002)	Fuch and Tessaring (1994); Schmidt (2003)	EMB (2000); FSB (2000)

Sources: EMB (2000); Neugart and Schömann (2002); Willems (1996); Wong *et al*. (2004)

Table 2.1 Overview of manpower planning practices

Country	Japan	Netherlands	United Kingdom	USA
Time horizon	1999 – 2010	2001 – 2006	2001 – 2006/2010	2000 – 2010
Interval for updates	5 years	2 years	1 year	2 years
Degree of disaggregation	N.A.	13 sectors, 127 occupational groups, 104 types of education	49 industries, 22 occupational groups	250 industries and 500 detailed occupations
Major data sources	Census, basic survey of employment structure	Labour force survey	Census, labour force survey combined with industrial data for employment status and gender, derived from establishment-based surveys	Census, labour force data, employment statistics
Who pays for the forecasts?	Ministry of Labour	Ministries of Research, Labour and Agriculture; Central Employment Board; LDC Expertise Centre for Career Issues	The research institute originally funded by the Department for Education and Employment (DfEE)	Ministry of Labour
Who does the forecasts?	Research Committee for Employment Policy	Independent research centre (ROA)	Independent research centre (IER)	Statistical Institute of the Ministry of Labor (BLS)
Who uses the forecast?	One of the major resources for the discussion of employment measures	Ministries of Research, Labour and Agriculture; individuals for educational choices; firms to forecast supply shortages; employment offices	Policymakers; sub-models exist which allow policy simulations on the regional level	Government agencies for training, education and immigration policies; career counselors; firms; individuals
Demand-side forecasting approach	Industry output is first obtained by input-output analysis. Labour demand by industry is estimated by putting these industrial outputs into the labour demand function considering trend of productivity. Opinions of expert group are incorporated into the forecasts.	Labour demand projections are made using the Athena model CPB macro-econometric models. Growth rate by occupation is obtained by explanatory model. Together with replacement demand produces estimates of job openings.	Using a multi-sectoral macroeconomic model plus disaggregation of the sectoral employment levels into employment status, gender and occupations by extrapolation of past trends; a replacement demand analysis which allows for occupational mobility.	Projections of the GDP and the major categories of demand and income are first derived by a macro-econometric model. The demand for hours and jobs is projected using structural equation functions. Occupational employment projections are then obtained based on an industry-occupation matrix.
Supply-side forecasting approach	Labour force by sex and age is estimated by putting the results of population projections into the labour force participation rate function.	Stock-flow approach is used to derive the labour force by education. Substitutions between occupations are considered.	Stock-flow model is used to derive the total number of qualified persons. Multiplying the projections of economic activity rates reaches manpower supply projection.	Multiplying the projected participation rates by population figures gives the labour force projection.
Implementation	Government, social partners	Much involvement of social partners in planning and design of qualification profiles	DfEE delegates responsibility to profit-making local partners that receive public funding; non-corporatist approach	Responsibility on the state level
Other feature(s)	Large governmental commission presents results and spurs public debate; part of the economic outlook debate	Besides the general occupational outlooks, the perspectives of school-leavers are shown	Additional special survey on skill shortages	Much of the material can be obtained from the Internet; every state is required to produce state employment projections
Reference(s)	Suzuki (2002)	Dekker *et al*. (1994); Cörvers (2003)	Lindley (2002); Wilson (1994)	Barnow (2002); BLS (2003)

Sources: EMB (2000); Neugart and Schömann (2002); Willems (1996); Wong *et al*. (2004)

Table 2.1 Overview of manpower planning practices (cont'd)

The basic data sources for the forecasts are quite similar across the whole range of the selected countries. Most analysts use annual labour force survey and census data to achieve a sufficient level of disaggregation of employment trends by industrial sector, major occupational groups and levels of qualifications. A major additional data source which has also found its way into identifying skills needs is the use of representative surveys among firms and experts.

Most of the countries commission independent research institutes to carry out their regular manpower forecasting activities. The research institutes affiliated to the ministry of labour or charged with the collection and publishing of statistical information and research reports take responsibility for producing and disseminating the results of the forecasts. In the United States, for example, the Bureau of Labor Statistics is an agency within the Department of Labor and publishes the *Occupational Outlook* available online.

Concerning the forecasting strategy, the methods for predicting quantitative manpower demand are generally more refined than the conventional manpower requirements approach, but often do not differ from this approach in essence. Most of the countries apply macroeconomic forecasts to form the starting points of the demand estimation; only the explanatory variables are not identical in all cases. The estimations of manpower requirements are obtained by establishing the relationship with industrial output. Subsequently, occupational effects are considered using either fixed coefficients or equations to derive occupational demand forecasts. In most cases, qualitative information such as employers' view and expert knowledge are incorporated to refine the projections. A more comprehensive review of manpower demand forecasting approaches is presented in the next chapter.

On the supply side, there are two widespread approaches for estimating the pool of workforce: (i) the stock approach, which forecasts the total supply of a specific type of labour, future manpower supply is derived applying the estimated participation rates to the projected labour force by considering the demographical changes; and (ii) the flow approach, which models the various flows of labour supply. In the latter method, a distinction is made between the flows of new entrants entering the labour market and the outflow from the labour market. The influx of newcomers consists primarily of school-leavers. The outflow of labour can be due to retirement or to early withdrawal from the labour market suh as married women or disabled workers. The Netherlands put enormous efforts into incorporating the substitution possibilities between the various occupational groups in order to model the shifts in the structure of employment. Even though the manpower planning models presented allow disaggregated occupational forecast, large uncertainties still remain because changes in the occupational structure revealed in the forecasts cannot perfectly be matched to changes in the skill composition of the labour force. The whole issue of how skills are related to types of education and occupation, including the measurements of skills, has recently started attracting the interest of researchers (e.g. Borghans *et al*., 2001).

2.3.3 Manpower planning practices in Hong Kong

National manpower planning

Essentially two sets of national manpower forecasts are being practised in Hong Kong: (i) those produced by the Educational and Manpower Bureau (EMB) of the HKSAR Government, and (ii) those produced by the Vocational Training Council (VTC). The EMB produces a series of sectoral manpower demand and supply projections once every five years, following the completion of the census or by-census which provides the latest information on population (EMB, 2000). One of the main purposes of manpower forecasting is to assist the government in meeting future education and training needs for the community.

The quantitative projections produced by the EMB comprise several components, viz the population projections, labour force projections and employment projections by industry sector, occupation and qualification. The latest statistical forecasting models were formulated using simple extrapolation, based on their respective employment data series from 1986 to 1999, cover all jobs based in Hong Kong in 41 economic sectors (FSB, 2000). The projected manpower requirements and supply were then examined and refined, upon the views of industry leaders, trade association representatives, academic experts and relevant Government bureau and departments obtained during the consultations. Although supplementary information was taken into consideration in finalising projection, the results were largely based on past behavior and historical patterns of the components.

The VTC independently generates manpower forecasts for 22 specific industries since the 1970s based on biennial manpower surveys. A weighted exponential smoothing time series forecasting technique was applied to project short- to medium-term manpower demand by skill level based on historical employment data acquired from the VTC's biennial manpower surveys. The estimated demand by skill level was then disaggregated by principal jobs using the job structure revealed in the latest survey. The supply of the manpower was estimated by calculating the inflow (e.g. expected quantity of graduates) and the outflow (e.g. retirement) in the labour pool.

Based on data collected in the manpower surveys, estimated expenditure on construction works in coming years, the wastage rates, technological change, and other considerations affecting the industry, the VTC Training Board matched assessed annual demand against the estimated future supply of occupational workforce. The adjustments to training programmes in the next two years are thereby recommended. The views of employers on their current employment levels and the qualifications of people in the occupations being surveyed, together with their expectations of the qualifications are incorporated in the forecasts (Wong, 1996).

Manpower planning for the construction industry

The Environment, Transport and Works Bureau (ETWB) has been estimating the manpower requirements for the Hong Kong construction industry since the late 1990s. On the demand side, 'multipliers' expressed in man-days per HK$million of contract expenditure were derived for each trade type under 48 categories of works based on a number of completed projects. The manpower demand can then be estimated by multiplying project expenditure and the labour multipliers correspondingly. The supply forecasting model is based on regression analysis of previous data sets, which accounts for various factors affecting construction labour supply such as wages and new entrants from training (Chan *et al*., 2002). A five-year forecast of the supply and demand of the construction labour is made for 2002-2006 at the sectoral level.

In addition to the ETWB's forecasts, the manpower projections produced by the EMB and VTC as mentioned also cover the construction industry. All these forecasts are valuable for assessing the manpower structure and training requirements of principal jobs in construction and related disciplines of the building and civil engineering industry in Hong Kong.

2.4 SUMMARY

Identifying and forecasting future skill requirements and implementing these requirements in the training system have long been the subject of intensive research efforts and academic discussions. The aim is to find the right number of workers with the right skills, in order to facilitate the development of industry enabling the maintenance of the necessary balance by various occupations in the labour market. A direct implication of manpower planning is the assistance to vocational training and education to minimise the uncertainty in the future labour market. Where agencies, such as VTC and EMB in Hong Kong, attempt to formulate policies to ensure future skill balance in construction, reliable sets of manpower forecasts are crucial requirements to facilitate the development of industry, and should be designed to maintain relative balance between manpower demand and supply in the labour market.

The fluctuations of construction output and mix of works caused recruitment difficulties and skill surplus in the 1990s. Clearly, an ability to forecast employment demand in the medium-term is important for the efficient planning of training in the local construction industry. This chapter has examined the relevance of manpower planning to the Hong Kong construction industry, and included the aims, importance and requirements of manpower forecasting in practice. In addition to local manpower practices, worldwide practices are also reviewed. This information provides an essential base for the development of manpower forecasting models. The model development also depends heavily on the selection and reliability of forecasting methodology and identification of key determinants. These issues are critically examined in Chapter Three and Chapter Four respectively.

CHAPTER 3 LITERATURE REVIEW – MANPOWER DEMAND FORECASTING MODELS

CHAPTER 3 LITERATURE REVIEW – MANPOWER DEMAND FORECASTING MODELS

3.1 INTRODUCTION

The assessment of the labour market and the forecast of its demand have posed challenges to researchers, employment policy makers, manpower analysts and educational planners for decades. Among the challenges, selecting an appropriate forecasting methodology is the most critical factor to generate accurate forecasts for effective manpower planning (Goh, 1998; Wong *et al*., 2003a). This chapter critically reviews the methodological approach of manpower demand forecasting at both project and industry levels, locally and internationally. Specifically, reliability and applicability of the manpower requirement forecasting models for the Hong Kong construction industry are evaluated against the model requirements identified and by applying an empirical analysis. The review and evaluation of models aim to identify enhancements for further development of the manpower demand forecasting approach for the construction industry of Hong Kong.

3.2 FORECASTING METHODOLOGIES AT PROJECT LEVEL

The majority of manpower demand forecasting models at the project level make use of the close relationship between manpower demand and project size to estimate the skill requirements in construction. In Hong Kong, the existing forecasting model adopted by the Environment, Transport and Works Bureau (ETWB) is based on the premise that, in each project type, projects will demand the same level of labour per unit of project expenditure and follow a standard demand pattern (Chan *et al*., 2006). It was identified as the 'labour multiplier approach' originally put into practice by Lemessany and Clapp (1978).

Utilising information collected from site returns of daily labour deployment and the project expenditure on past projects, the labour number for each trade in the form of man-day per million-dollar (labour multiplier), covering various markets including public works, railway works, and other public utilities, are derived as shown in Equation 3.1. The estimated labour demand by occupation can then be projected by multiplying the corresponding multipliers and estimated project expenditure as illustrated in Equation 3.2. Aggregating the occupational manpower demand provides the estimation of the overall labour requirements for a construction project.

$$M^{s}_{jx} = \frac{D^{s}_{jx}}{E^{s}_{jx}} \tag{3.1}$$

$$D^{s}_{j(est.)} = \sum_{x} M^{s}_{jx} \cdot E_{x(est.)} \tag{3.2}$$

where M^{s}_{jx} is labour multiplier of trade s at stage *x* of the project type *j*, D^{s}_{jx} is labour deployment (man-days) of trade *s* at stage *x* of the project type j, E^{s}_{jx} is project expenditure (HK$million) at stage *x* of the project type *j*; $D^{s}_{j(est.)}$ is estimated total labour demand of trade *s* for a type *j* construction project, and $E_{jx(est.)}$ is estimated project expenditure at stage *x*.

Chan *et al*. (2003), using simple regression analysis, further developed a forecasting model to estimate the total labour required for any given type of project using a non-linear labour demand-cost relationship. This multiplier approach complies with the factors identified by Agapiou *et al*. (1995a), which utilises the intimate relationship between the project-based manpower requirements and the volume of work within a particular market sector. Poon *et al*. (1996) adopted a similar forecasting approach to estimate the requirement of technicians in the Hong Kong construction industry, based solely on the multiplier deriving from the employment record of technicians and contract sum.

Analogous to the labour multiplier approach, Proverbs *et al*. (1999) presented the findings of an international study of contractors' productivity rates, from which a multiplier approach to estimating labour requirements at the inception stage was proposed for typical buildings in France, Germany and the UK. Planned productivity rates formed the basis of the estimate, being used to generate labour estimator factors. These factors were defined as the man-hour required per square meter of the building's gross floor area. Thereby corresponding factors were applied to predict man-hour requirements for a concrete framed building once the gross floor area was known.

In the United States, University of Texas researchers developed a system for predicting manpower requirements associated with preconstruction activities for the Texas Department of Transportation. Regression equations were developed which also used the project cost as the independent variable to forecast engineering-design labour hours categorised by project type (Persad *et al.*, 1995). This research concluded that construction cost and project type are excellent predictors of engineering manpower requirements.

Following this research, Bell and Brandenburg (2003) adopted similar simple linear regression analysis to predict overall manpower requirements for the highway construction projects of a given type and cost in the South Carolina Department of Transportation (SCDOT) of the United States. Based on the labour demand-cost relationship, the overall requirements were then adjusted to predict manpower requirements for individual employee classifications using task allocation percentages obtained from a questionnaire survey. The output from the model served as input into commercially available critical path method scheduling software to facilitate manpower planning and resource levelling.

The above-mentioned forecasting methods are designed to utilise the causal relationship between manpower demand and its determinants, i.e. construction cost or labour productivity rate, for forecasting purpose. Fixed coefficients are established for different categories of building, housing and civil engineering works. The categorisation allows different multipliers to reflect the effect of the different technologies and labour mix used for various project types, and thus different labour productivity rates so as to obtain more reliable estimations. Forecasting using this coefficient approach is relatively simple and has been verified to be reasonably reliable (Persad *et al*., 1995; Proverb *et al*., 1999).

As with most forecasting models, the fixed coefficient forecasting approach has its constraints. Frequently updated to take into account any changes in technology and labour mix, which will be reflected in the new sets of labour multipliers. However, this requires considerable effort and expense (Wong *et al*., 2004). The time lag to adjust the multipliers would also be a severe constraint on the fixed coefficient approach to reflect prudently and timely the changes of technology, competition and legislation. Regular and frequent updating of coefficients is thus crucial for obtaining accurate forecasts. Another constraint in using this kind of forecasting methodology is that it depends heavily on the past data and on the implausible assumptions, which makes use of the sole relationship between the specific independent variable and the labour demand. Verification of this aspect is therefore important when developing this type of forecasting model.

3.3 FORECASTING METHODOLOGIES AT INDUSTRY LEVEL

The major manpower demand forecasting approaches at the industry level can be broadly categorised into four clusters: (i) time series projection; (ii) 'bottom-up' coefficient approach; (iii) 'top-down' approach and (iv) labour market analysis (Wong *et al*., 2004). The rationale, strengths and limitations of these latest manpower demand estimating methodologies are examined. The merits and applicability of the four categories of forecasting methodologies are then compared based on various model selection criteria.

3.3.1 Univariate time series projection

The basic characteristic of a time series extrapolation on the forecasting manning levels is its restriction of the stochastic information by examining a relationship solely between the past behaviour and time and then extrapolating the trend into the future (Bezdek, 1975; Goh and Teo, 2000). Examples of technique for univariate analysis range from a simple deterministic model such as linear extrapolation (naïve model) to complex stochastic model (e.g. Box-Jenkins models) for adaptive forecasting (Pindyck and Rubinfeld, 1998). In general, sophisticated methodologies provide better estimates than extrapolation of existing trends or other simple techniques (Rumberger and Levin, 1985).

As introduced in Chapter Two, since 1970s the Vocational Training Council (VTC) in Hong Kong produces forecasts of industrial manpower requirements using a weighted exponential smoothing forecasting technique. The weights used form a geometric series with heavier weights given to the more recent data, i.e., the forecast is more dependent on the recent data. In addition, the smoothing technique is applied in order to smooth out the random fluctuations in past data so as to reveal the trends (Wong, 1996; Suen, 1998). It is based on an assumption that results from *n* survey are available,

$$\bar{\mathrm{D}}_t = \frac{\mathrm{D}_t + \mathrm{D}_{t-1}(1-A) + \mathrm{D}_{t-2}\ (1-A)^2 + ...}{\sum_{n=0}^{t-1}(1-A)^n} \quad \text{for } t > 1 \text{ for all D} \tag{3.3}$$

where D_t is the manpower demand at the time of survey; $0 \le A \le 1.0$. The larger the value of A, the more heavily the recent data are weighted. The A value can be adjusted to give optimum curve fitting such that either the absolute error or the mean square error of the curve is minimum.

The ratio of the weight moving average $\mathrm{R}_t = \dfrac{\bar{\mathrm{D}}_t}{\bar{\mathrm{D}}_{t-1}}$ is then similarly operated on as for the basic survey data to give the weighted ratio such that:

$$\bar{\mathrm{R}}_n = \frac{R_t + R_{t-1}(1-A) + R_{t-2}\ (1-A)^2 + ...}{\sum_{n=0}^{t-2}(1-A)^n} \quad \text{for } t > 2 \text{ for all R} \tag{3.4}$$

The forecast value for the first period immediately following the most recent survey, i.e. D’t+1, is then given by

$$\mathrm{D'}_{t+1} = \bar{\mathrm{R}}_t\ \bar{\mathrm{D}}_t \tag{3.5}$$

Forecast values for later periods, i.e. D'_{t+2}, D'_{t+3}, D'_{t+4} can then be found by repeating the above procedures. Univariate time series projection for forecasting manpower requirements is also employed by the Education and Manpower Bureau (EMB) of the Hong Kong SAR Government, the Central Office for Education in Finland, the Department for Education and Employment in the UK, and the Government of Poland (Tessaring, 2003; Wong *et al*., 2004).

Univariate projection is fairly reliable, relatively simple and inexpensive (Bartholomew *et al*., 1991). It also helps discourage introduction of personal bias into the forecasting process. Forecasters can focus on considering the underlying trend, cyclic, and seasonal elements, and take into account the particular repetitive or continuing patterns exhibited by past manpower-use data (Bryant *et al*., 1973).

However, because of the limited structure of time series projection, it is only suitable for producing short-term forecasts (i.e. one to four intervals ahead). Another limitation is that it does not give insight into the factors causing the changes in manpower requirements and occupational structure. Hence, evaluations of forecasts are impeded, such as new technology, productivity and the wider economy (Wong *et al*., 2004). Weakness also arises from the assumptions that the future will be a continuation of the past. Extrapolation produces large forecast errors if discontinuities occur within the projected time period. It is also disadvantaged by the lack of explanatory capabilities, thus not suitable for applications where explanation of reasoning is critical (Goh and Teo, 2000).

3.3.2 'Bottom-up' coefficient approach

The labour multiplier forecasting model described in section 3.2 is the basis of the 'bottom-up' coefficient approach. The labour demand by trade is initially derived by multiplying corresponding labour multiplier with estimated project cost. Aggregating the project-based manpower demand deriving from all future projects provide the prospect of the overall industrial labour market requirements. Rosenfeld and Warszawski (1993) and CWDFC (2002) applied this multiplier approach for forecasting the labour demand for the construction industries in Israel and Alberta respectively. Smith *et al.* (2000) estimated the health professional demand by multiplying future utilisation rate for different provider settings by projected population in Shelby County, Tennessee. McClean and Reid (1993) also utilised the nursing hours per patient ratio as a tool for nurse demand forecasting for the National Health Service sector in the United Kingdom.

As discussed, the advantage of this type of forecasting method is that the categorisation allows different multipliers to reflect the effect of the different technologies and labour mix used for various project types. The forecasting rationale is simple and straightforward. However, apart from the constraints on the multiplier models pointed out earlier, it is demanding to collect past employment records and the details of the future project estimates, especially in the private sector and the maintenance sector for the forecasting at the industry level (Wong *et al*., 2004).

3.3.3 'Top-down' approach

Top-down approach is another common method for forecasting industrial or national manpower demand. The rationale of this method is linking the aggregate manpower requirements to the output of the industry and to the developments in the rest of the economy, i.e. it is assumed that a growth of a certain industry will lead to proportional growths of the demand for manpower within the industry (Willems, 1996; Uwakweh and Maloney, 1991). The occupational demand is then estimated by predicting the shares of individual occupations. Amongst the variety of methodologies used to derive manpower forecasts, the top-down forecasting approach is the dominant methodology (Debeauvias and Psacharopoulos, 1985; Hopkins, 2002; Wong *et al*., 2004). It has been widely adopted by various institutes in both developed and developing countries, including the USA, the United Kingdom, Germany, Netherlands, Italy, Czech, France and Sri Lanka.

The origin of applying a 'top-down' approach in the field of manpower forecasting is the manpower requirement approach applied in the OECD's Mediterranean Regional Project (MRP) as discussed in section 2.3. Irrespective of their analytical basis, top-down models initially tend to use quantitative techniques related either to the input-output methodology or econometric techniques to estimate sectoral output (Infante and Garcia, 1990). Given an estimate on the level of output in various economic sectors, the input-output methodology determines the volume of total industrial employment. Technological change and investment can generate significant alterations in the input-output coefficients and consequently in the demand for manpower.

The second group of techniques concerns the estimation of models through econometric and/or simulation procedures. The procedures include formulating a set of equations describing the complex interrelationships of the sectoral manpower demand and a number of corresponding economic variables (Campbell, 1997). It employs statistical and mathematical methods on the analysis of economic observations, with the purpose of giving empirical content to verify or refute concurrent economic theories (Maddala, 2001). For instance, the Institute of Employment Research (IAB) in Germany exploited macroeconomics models to give several scenarios of the future 'labour landscape' (Fuchs and Tessaring, 1994). The scenario results generated from a multi-equation simulation model comprising demographic trends, international economic development, the rate of technical progress, price and wage-price mechanism and the assumed economic policy (Willems, 1996).

To derive the manpower demand by occupation, the simplest approach is to take the most recent available estimates and assume constancy. In practice, the VTC estimated the occupational demand by assuming the job structure constant over the projected period (Wong, 1996). Hopkins (2002) also applied this methodology to forecast the employment demand by occupation in Sri Lanka. A variant on this approach would be to calculate the average percentage shares over the most recent five years or so, thus smoothing over the output cycle. Such approaches provide an easily understood basic method of projection. However they fail to use the information available in the time series data, therefore the trend of the occupation cannot be captured (Briscoe and Wilson, 1993).

More recently, methods adopted for forecasting occupational share have been more sophisticated, allowing for changing coefficients and responses to economic variables (Wong *et al*, 2004). A basic pace is to test the series for the significance of a linear trend (Briscoe and Wilson, 1993). The most primitive time trend forecasting model can be written:

$$P_i = \alpha + \beta \, (\text{TIME}) \qquad (3.6)$$

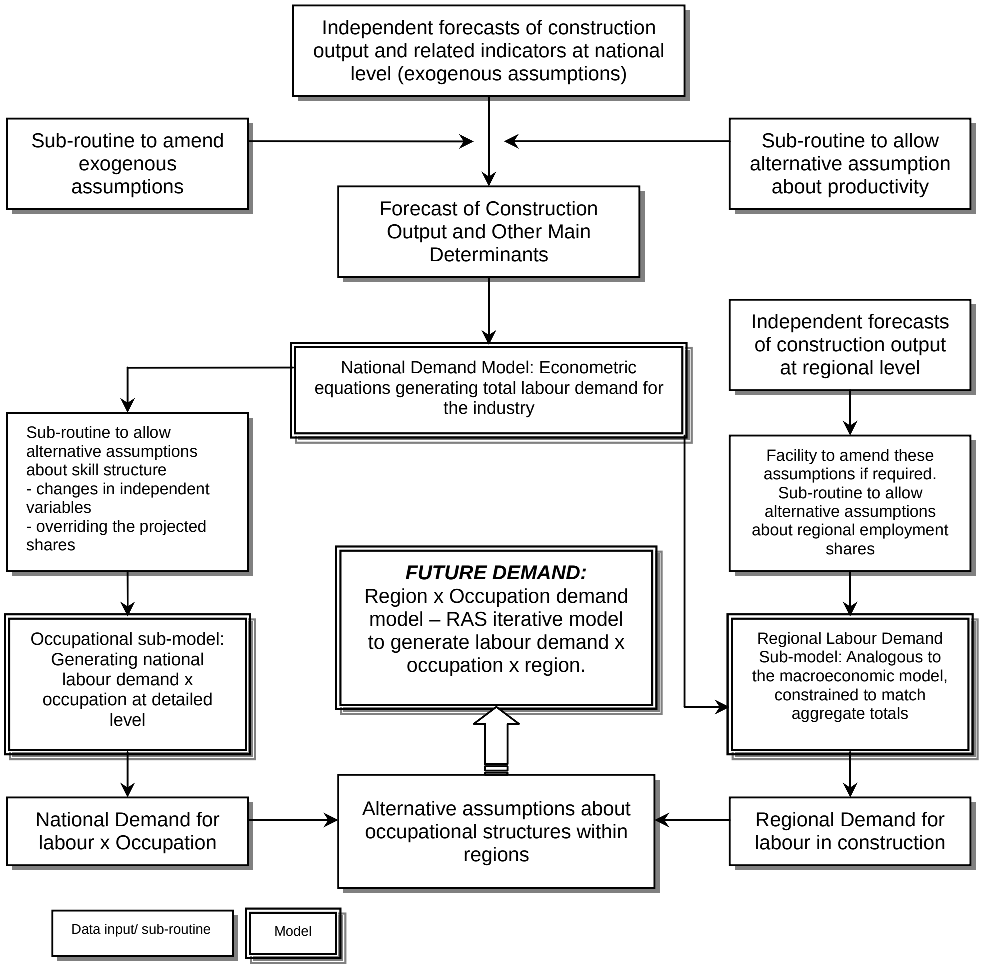
where P_i is the percentage share for i^{th} occupation (i = 1, 2, 3…); TIME is a continuous variable capturing the linear time trend. A constraint is applied to ensure that all the occupational shares sum to unity. A number of variants on this basic form are possible, such as an exponential relationship or a quadratic, where occupational share exhibits evidence of accelerating change. The Institute for Employment Research (IER) in the UK and the Ministry of Human Resources Development Council (HRDC) in Canada also apply this method to develop occupation-industry matrices for occupational forecasts (Smith, 2002).

An important step towards improving the time trend model is to allow for cyclical influences, as represented by changes in total construction output and the mixture of works over the economic cycle as adopted by Briscoe and Wilson (1993). Occupational share model can be usefully expanded to incorporate the effect of these variables:

$$P_i = \alpha + \beta_0 \text{ (TIME)} + \beta_1 \text{ (OUTPUT)} + \beta_2 \text{ (MIX)} \qquad (3.7)$$

where OUTPUT is total construction output; MIX is mixture of construction output in different sectors. Such model offers more flexibility in projecting occupational shares and thus more reliable forecasts. The increase in computer sophistication in the past two decades has further provided an unprecedented capability for long range forecasting.

The forecasting methodology currently adopted in the UK is a typical example of the top-down forecasting approach. Briscoe and Wilson (1991) adopted the co-integration technique to establish a long-run equilibrium relationship between labour demand and *inter alia* output and real wages for the engineering sector. Following the modelling methodology of Hendry (1985), a general dynamic specification was derived with lags on the significant variables. Ball and Wood (1995) also attempted to model the effect of the changes in construction output, disaggregated output, use cost of capital and real construction wages on employment in the industry using the same econometrical modelling technique. A similar model with additional interest rate variable was derived by Briscoe and Wilson (1993) for the construction industry in the UK as outlined in Figure 3.1. This model is further implemented for forecasting the structure of employment in the UK by the Institute for Employment Research (IER) (Wilson, 1994).



Sources: Briscoe and Wilson (1993)

Figure 3.1 Scheme outline of a manpower demand forecasting model for the UK construction industry

The share of each occupation in the national employment total was derived from a separate set of equations which make the respective occupational shares a function of trend, output cycle and various work mix variables using regression analysis. The national employment forecasts were also broken down into regional forecasts using significant explanatory variables in the regional equations. Diagnostic tests were conducted to confirm the efficiency of the model specifications.

Top-down forecasting technique is capable of projecting long-term quantitative skilled manpower needs (Campbell, 1997). This technique is readily comprehensible by utilising statistics and has remained popular with economists, workforce planners and policy makers because of its structured modelling basis and acceptable forecasting performance. Econometric modelling surpasses other methodologies by its dynamic nature and sensitivity to a variety of factors affecting the level and structure of employment, taking into account indirect and local inter-sectoral effects. It adequately deals with interaction between different labour market segments and substitution processes between occupational groups (Richter, 1986; Görvers, 2003).

Nevertheless, previous evaluation work on the top-down approach (e.g. Hughes, 1991; Amjad *et al.*, 1990; Hinchliffe, 1993) conclude that the approach is problematic as it lacks allowance for changes in business environment, job turnover and occupational mobility. It might be, however, possible to produce superior equations by introducing a wider range of work mix indicators and using several work mix or labour mobility determinants to cope with the constraint. Another shortcoming is that the reliability of the top-down method depends essentially on the accuracy of the plausible assumptions especially in the behavioural context of social science. It is difficult for models based on projections of the macroeconomic variables such as interest rates and overall output to predict manpower needs because of the obscurity in these changes of economic activity and technology. The sensitivity of the forecast to various determinants, however, can be assessed by developing a range of scenarios rather than a ‘fixed point’ forecast. In addition, considerable care is required in the issue of multicollinearity to prevent drawing misleading inferences as many totally unrelated variables might exhibit spurious correlation (Pindyck and Rubinfeld, 1998).

3.3.4 Labour market analysis

Rather than relying exclusively on sophisticated long-term forecasts, workforce planners increasingly bring labour market analysis (LMA) approaches into play in the field of manpower planning. Psacharopoulos (1991) was one of the early academicians who refuted the usefulness and the rationale behind the tradition manpower planning practice, amid sustained criticism of the traditional approach and persistent view to replace it with the LMA. The LMA is based on 'market signals' to identify job opportunities and skill requirements (Campbell, 1997). Examples of the signals include movement of relative wages, employer screening practices, enrolment data, employment trends by education and training, unemployment rate by education, and job advertising. It focuses on education and training qualifications rather than on occupational classifications, with the aim to estimate the economic returns on investment in specific skills (Middleton *et al*., 1993).

The findings from LMA are primarily of value for providing indications of any mismatches between employers' demand for people with differing levels of qualifications and the likely number of available workforce. Planners can monitor labour market conditions, and assess skills strategically important to economic development by assessing the findings (Hopkins, 2002). This approach is particularly useful when existing data are inadequate to build a sophisticated time series model or econometric equations. A tracer study of graduates, for instance, helps assess whether the skills supplied by institutions match the requirements of the labour market. Subsequently, cautious adjustment of training enrolments can be recommended (Debeauvais and Psacharopoulos, 1985).

Consensus procedures or key informants survey has been an alternative feasible approach for estimating manpower requirements since 1970s (Bezdek, 1975). It involves the polling of experts or employers closest to the field to obtain their opinions as to what the value of a particular variable is likely to assume in the target year. They are the ones who decide on hiring and are familiar with the demand and supply of the market. Although the ‘manpower requirements approach’ dominates the manpower forecasting practice in the developed countries, macroeconomic approaches are relatively deficient in providing detailed insights into specific and new qualification and skill requirements. Key informants are the appropriate sources for this particular aspect of labour demand market (Campbell, 1997).

Chan and Wong (2004) applied this methodology to assess the employment opportunities for Hong Kong-trained construction-related professions. The German Employers’ Committee on Vocational Training also made use of questionnaire surveys for experts in construction to identify training needs (Bromberger and Diedrich-Fuhs, 2003). The survey findings provide practical recommendations for central government, professional associations or training bodies to take possible initial or further training measures. A more systematic approach to collect experts' consensus, the Delphi technique, was also employed to assess the future prospects in the labour market areas (e.g. Rajan and Pearson, 1986; Van Wieringen *et al*., 2002), which was initiated by Milkovich *et al*. (1972) for planning manpower. The decisive difference between these quantitative methods is that prediction is not only based on calculations but also backed up by the strength of experts' knowledge and sources of information.

A combination of LMA with other forecasting approach is not rare in the practice of manpower planning. Subsequent to the time series projections by the VTC in Hong Kong described previously, the forecasts were verified and adjusted by the training boards based on employers' short-term forecast market trends, technological development and future expectation. The replacement demand factors including normal retirement, age of existing workforce, and mobility of workers inside and outside industries were also considered.

The Human Resource Development Council (HRDC) in Canada adopted labour market signalling and manpower forecasting to provide information about future labour market conditions, known as 'Job Futures' (see www.hrdc-drhc.gc.ca/JobFutures). Based on a set of economic models and forecasting tools as well as consultation with private and public sector experts, it provided comprehensive information for individuals and advisors involved in the education and career planning process. The Institute for the Development of Workers' Vocational Training (ISFOL) in Italy also utilised employer survey and econometric models to obtain future skill needs (Gatti, 2003).

For short-term assessment of training needs, LMA is recommended as a tool to help adjust training programmes to the changes in market circumstance and, thereby, reduce inefficiencies (Middleton *et al*., 1993). It can yield flexible and responsive indicators of workforce supply and demand imbalance in the labour market and give early warning signals about forthcoming changes (Castley, 1996b). In addition, the information is valuable to occupational training planners, who can use it in determining the need for training in a particular occupation in a comparatively easy and inexpensive way (Campbell, 1997). LMA is therefore a useful adjunct to conventional manpower analysis through advocating the need for wage and employment trends, not only to guide training decisions but also to evaluate how well labour markets are functioning.

Nevertheless, the LMA has been heavily criticised. This is centred upon the lack of any firm theoretical foundation as well as the practical problems of ensuring that all respondents are adopting common assumptions about the future scenario and that their responses are mutually consistent (Agapiou, 1996). In the case of acquiring knowledge from experts, it is based heavily on opinions, requires costly executive time to carry out, and takes the risk that an expert or an employer may not be able to provide accurate forecasts. This qualitative information collected may lack objectivity. It may contain individual bias and be distorted because of personal views, economic uncertainties or business conditions (Bryant *et al*, 1973). Additionally, individual employers are unlikely to make consistent views about the growth and structure of output over the forecasting period. Data collected from job advertisements or tracer studies are also constrained to certain sectors of the economy (Campbell, 1997).

3.3.5 A comparative evaluation

The industry-based forecasting approaches introduced are first evaluated by assessing their complexity in terms of input/output requirements. Table 3.1 reveals the input and output requirements of the four broad categories of forecasting approaches, in a matrix form. It indicates that the time series projection approach requires minimal data preparation and level of analysis among other methods. In contrast, bottom-up and top-down approaches need vast amount of statistics and records for estimation and the latter may involve sophisticated modelling and analysis for producing long-term forecasts.

	Input Requirements		Output
	Data	**Tool**	
Time Series projection	Historical records (~20 years) of the targeted series	Projection techniques, e.g. exponential smoothing, Box-Jenkins modelling.	• Short-term (1-year ahead) aggregated manpower demand forecast • Large forecast error if discontinuities occur within the projected time period
Bottom-up approach	• Detailed labour returns and costs of the past projects breakdown by various market • Estimated future project costs	Large size of database but rather simple calculations	• Project-based occupational manpower demand • Industry-based occupational manpower demand by summing all estimated project-based demand
Top-down approach	• Extensive macroeconomic statistics, e.g. GDP, sectoral output, unemployment rate, productivity, interest rate, wage. • Future growth of the economy and relevant determinants	Extrapolations, Advanced econometrics modelling e.g. cointegration, vector error correction modelling, simulation, sensitivity analysis.	• Long-term industry-based aggregated manpower demand • Occupational and regional manpower demand can be obtained by extrapolation, using labour-productivity factor or experts' judgement.
Labour Market Analysis	• Labour market signals, e.g. movement of relative wages, enrolment data, occupational employment trends and unemployment rate, job advertisement.	Relative simple analysis, e.g. interviews, surveys, tracer study.	• Existing mismatch signals (qualitative and quantitative) in the labour market • Employers' view of future prospect of individual occupations

Table 3.1 Input/Output requirements of the manpower demand forecasting methodologies

Table 3.2 summarises the relative merits of the four categories of manpower demand forecasting techniques based on the evaluations made earlier. The matrix, adapted from Bryant *et al*. (1973), facilitates the comparison of the advantages of the four categories of forecasting methodologies and permits the rapid evaluation of a method's relative merit with respect to each of the critical selection criteria. The cells of the matrix contain the following code letters: E (Excellent), G (Good), F (Fair), P (Poor), VP (Very Poor). The methodologies were evaluated with respect to the following criteria:

- *Forecasting* – Ability to estimate future manpower needs or the effects of some expected manpower problem accurately;
- *Scheduling* – Time of the satisfaction of anticipated manpower requirements;
- *Cost* – The costs for delivering manpower demand forecast;
- *Uncertainty* – Assessment of the uncertainty of future events;
- *Time horizon* – Relevant time spans: L – ten years or more; M – approximately five years; S – less than one year;
- *Aggregate* – Ability to forecast overall manpower needs;
- *Individual* – Ability to determine the requirements for an individual job or a group of jobs;
- *Testing policy changes* – Determination of effects of changes in governmental policy upon costs or required manpower levels;
- *Hierarchy level* – The type of personnel the method may be applied to: U (Upper) to management or executive positions; M (Middle) supervisory and technical positions; L (Lower) labour such as production, site workers, clerical;

- *Static versus dynamic* – Situations at a point in time versus changes and effects over a period of time.

Criteria	Fore-casting	Sche-duling	Cost	Uncert-ainty	Time horizon			Aggre-gate	Indivi-dual	Test policy	Hierarchy			Static	Dynamic
					L	M	S				U	M	L		
Time series projection	F	G	E	P	P	F	G	G	P	VP	F	G	G	F	P
Bottom-up approach	G	F	P	P	P	F	G	F	G	P	G	G	G	G	P
Top-down approach	G	P	P	G	G	E	F	G	G	G	G	G	F	G	E
LMA	F	P	F	F	P	F	E	P	G	F	G	F	VP	G	F

Note: E - Excellent, G - Good, F - Fair, P - Poor, VP - Very Poor

Adapted from Bryant *et al*. (1973)

Table 3.2 Evaluation of the manpower demand forecasting methodologies

Although time series projection can provide prompt and economical forecasts, it is not sensitive to the effects of changes in governmental or organisational policy upon required manpower levels and it is more appropriate to be used for short-term forecasts. Similarly, LMA approaches are only able to detect the occupational mismatch in the labour market in a short time span. Another limitation of the LMA is that the ‘signals’ for semi-skilled/unskilled workers are usually not accessible which adversely affects the comprehensiveness of the forecasts.

The forecasts given by top-down approach are considered to be relatively more reliable, primarily because of its ability to capture the determinants of the manpower requirements and their reliance on econometrical modelling with rigorous verifications (Wong *et al*., 2004). In addition, the top-down approach surpasses other forecasting methods by its capability of forecasting medium- to long-term projections, the qualifications of assessing the uncertainty of future events and managing dynamic situations in the labour market. In addition, it allows the testing of "what if" scenarios, such as assessing the impacts of major development projects or migration flows on employment and economic output, notwithstanding sophisticated calculations that it might involve. They also have the advantage of being based upon economic theory, which ensures that outputs are consistent with what is known about the fundamental workings of an economy. However, it is useful to further verify the estimations of occupational demand by other complementary information from the LMA.

Two additional important remarks must be made here. First, although a number of the forecasting methodologies were developed in recent times, no one approach was guaranteed as the most accurate method in all circumstances. However, intelligent use of statistical methods is still vital to predict future skill needs (Bartholomew *et al.*, 1991). Second, the evaluations are subjective in nature. Nevertheless, they can help policy makers or education planners select the most appropriate forecasting method. In spite of this, the final decision must not be solely based on a matrix drawn up externally. Decision makers are required to digest the material on the various manpower forecasting methods and reach a decision from the study. Further considerations such as the desired form of forecast; availability of data; ease of operation; and users' requirements of the forecasts should be taken into account when selecting an appropriate forecasting technique (Bowerman and O'Connell, 1993).

3.4 AN EVALUATION OF FORECASTING MODELS IN HONG KONG

As introduced in section 2.3.3, EMB, VTC and ETWB respectively produce a range of predictions of manpower demand for the construction industry of Hong Kong. This section further evaluates the applicability and reliability of these local models. The evaluation focuses on two aspects: (i) the stakeholders' requirements of the manpower forecasting model as identified in section 2.2.3; and (ii) the predictive accuracy of the models with corresponding forecasts in comparison with actual data. It aims to identify improvement options for manpower demand forecasting in the industry.

Table 3.3 summaries the results of the case study, which provide an overview of the outputs and process of manpower forecasting for the construction industry of Hong Kong. It also shows the extent to which the current forecasting practices meet the expectations of the end-users. In general, the existing models can somewhat satisfy these requirements in terms of content and process. There is, nevertheless, room for improvement in the manpower forecasting techniques and procedures in Hong Kong. Given the limitations of the manpower forecasting approaches, they could not explicitly reflect the changing economic conditions and the trends of the future labour market of the construction industry. The ability to estimate the future industrial manpower demand and supply accurately and the reduction of burdens on data providers are also criteria for improvement.

Requirements *(Scope and Content)*	**EMB**	**VTC**	**ETWB**	**Requirements** *(Forecasting Process)*	**EMB**	**VTC**	**ETWB**
1. Responsive to changing economic conditions and trend	F	F	P	9. Accurate and updated data information	G	G	F
2. Ability to predict aggregate labour force, employment and unemployment accurately	F	P	P	10. Valid assumptions and forecasting approach	F	F	G
3. Complete industry coverage	E	F	P	11. Easy data handling and management	G	G	F
4. Capable of providing data on future qualification or skills needs	F	G	F	12. Minimal burdens on providers of data	G	P	P
5. Capable of forecasting future qualifications supply	G	P	G	13. Capacity for frequent updates	P	F	G
6. Able to predict labour demand at project level.	VP	VP	G	14. Ability to provide a range of forecast	G	G	P
7. Planning for education and training	F	G	P				
8. Appropriate time frames	F	E	G				

Note: E - Excellent, G - Good, F - Fair, P - Poor, VP - Very Poor

Table 3.3 Comparison of VTC and ETWB approach with suggested requirements for the Hong Kong construction industry

A reliable forecast is the one which yields the forecast error with the minimum variance (Pindyck and Rubinfeld, 1998). The forecasting performances of the three models were evaluated by two common measures of accuracy, namely the mean absolute percentage error (MAPE) and Theil's U inequality coefficients. The mathematical expressions of MAPE and U statistics are expressed in the Equations 3.8 and 3.9. The former reveals the deviation of predicted and actual figures interpreted as the percentage error of the forecasts. The scaling of Theil's U coefficient falls between zero and unity (Theil, 1978). If U = 0, the forecast error is zero for all t reflecting prefect fit; if U =1, it indicates that the predictive ability of the model totally fails. The scaling of this measure weighs error relative to the actual movements of the predicted variable; it produces an appropriate way to standardise for differences between forecasting models. This assessment is an objective and stringent method as the data to build the model is distinct from that used to test its accuracy.

$$\text{MAPE} = \frac{1}{n}\sum_{t=1}^{n}\frac{|(Y_t^s - Y_t^a)|}{Y_t^a}\times 100 \tag{3.8}$$

$$\boldsymbol{U} = \frac{\sqrt{\frac{1}{n}\sum_{t=1}^{n}(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{n}\sum_{t=1}^{n}(Y_t^s)^2} + \sqrt{\frac{1}{n}\sum_{t=1}^{n}(Y_t^a)^2}} \tag{3.9}$$

where Y_t^s is forecasted value of Y_t, Y_t^a is actual value of Y_t and n is the number of periods.

The forecasts of the EMB and VTC models produced in the recent five years were examined. For the EMB's forecasts, the actual demand of construction manpower was obtained from the figures of employed persons plus the vacancy by broad occupations. The vacancy figures acquired from VTC's biennial *Manpower Survey Reports* were subsequently applied to the corresponding employment level to derive the manpower demand. The projected manpower requirements were then compared with the latest actual figures in the forth quarter of 2004.

As only recommended numbers of trainees were estimated by the VTC, the predicted vacancy figures are compared to the projected number of graduates in 2004. If the projected supply as suggested by the VTC matches the vacancy, the forecasts are validated as precise and reliable. According to the normal training routes in Hong Kong as stated by the VTC (2003), it was assumed that it takes 7 years to be trained as Professionals/ Technologists, i.e. 3-year education plus 4-year working experience. Similarly, it was assumed that 4 years and 2 years are required to train a technician and a tradesman respectively (see Appendix C). Applying estimated 3% wastage rate, due to retirement, death, change of jobs, deployment outside Hong Kong and emigration, to the employment figures in 2003 as assumed by the Training Council, the vacancy figures of each occupation in 2004 were derived.

Lastly, forecasting performance of the multiplier model adopted by the ETWB was assessed by comparing the actual project labour demand with predicted results. An out-of-sample test group comprising 64 projects was used to test the reliability and sensitivity of the forecasting model. The results of the assessment are summarised in Table 3.4. A detailed report of the assessment is presented in Wong *et al*. (2005a).

	MAPE	*U*
EMB (Total manpower demand in 2005)	26.80%	0.1182
EMB (Broad occupational demand in 2005)	32.05%	0.1165
VTC Broad Occupations (2004)	90.33%	0.3553
VTC Key Occupations (2004)	83.31%	0.2709
VTC Broad Occupations (2002)	41.88%	0.1859
VTC Key Occupations (2002)	47.46%	0.2539
ETWB (64 out-of-sample projects)	21.16%	0.1183

Note: MAPE: mean absolute percentage error; *U*: Theil's *U* inequality coefficients

Table 3.4 Evaluation of manpower demand forecasts for the Hong Kong construction industry

The empirical evaluation revealed that generally the performance of manpower demand forecasts for the construction industry in Hong Kong is unsatisfactory. The MAPEs of nearly all forecasts are over 20%. The Theil's U statistics indicate that EMB provided the most reliable forecasts (U = 0.1165). However, in comparing the actual occupational demand and the projected figures estimated by EMB, only two broad groups, namely, professionals and clerks had the magnitude of the prediction MAPE lower than the general acceptable limit of 10%. It is worth noting that manpower demand projections in all occupational groups produced by EMB were overestimated. Most of the training requirements recommended by the VTC are also oversupplied. These large forecast errors occured possibly because the forecasters failed to predict the severe downturn in the local property and construction sectors and the drastic reduction in public sector building works after 1999, which rigorously affected the demand for manpower in the construction industry. In addition, comparing the intake number of trainees recommended by the VTC with the actual vacancy over two years, the accuracy of projections produced had not been improved. The large error rose in 2004 primarily because the speed of industrial recovery was overrated, and therefore the manpower demand.

Since the univariate time series projection approach failed to estimate future manpower demand, it is deemed that this approach is not a preferable forecasting method for the construction employment outlook. Econometric modelling techniques such as vector autoregressive/error correction model may offer more reliable estimations of the labour resources demand for the construction industry, as they can assess and impacts of major development projects on employment and economic output.

At the project level, the ETWB model was also not adequately capable of predicting labour demand. Attempts have been made to cluster the projects by scale and type of project, but no significant difference on the prediction error was found. The assumption based on the relationship between the labour demand and the contract value might not be adequate to capture the labour demand specification. Further analysis should be carried out to improve the accuracy and reliability of the existing multiplier model. The improvement can be either through, for example, incorporating more samples into the model or inserting relevant multiple variables to obtain a more reliable forecasting model.

3.5 SUMMARY

The strengths and weaknesses of worldwide manpower demand forecasting methods at both project level and industry level are reviewed in this chapter. The review reveals that the fixed coefficient approach is the most common and reliable forecasting method to predict the project-based manpower demand. At the industry level, the comparison concludes that the ‘top-down’ forecasting approach offers the greatest potential for the timely production of reasonable reliable manpower demand forecasts. These two methods are therefore adopted to develop the forecasting models for estimating construction manpower demand at respective levels for this study.

Additionally, the reliability and applicability of the manpower demand forecasting models for the Hong Kong construction industry have been examined against users' requirements and an empirical analysis. It was found that the local existing models failed to provide accurate manpower demand forecasts. More robust causal models should thus be constructed to facilitate effective manpower planning in construction at both project and industry levels. On the one hand, additional samples and relevant variables should be incorporated into the fixed coefficient approach to provide more reliable project-based manpower demand forecasts. On the other hand, econometric modelling technique is recommended to be adopted for deriving the causal relationship between construction employment and economic environment at the industry level. The next chapter reviews the factors affecting the manpower demand at project level and industry level.

CHAPTER 4 LITERATURE REVIEW – DETERMINANTS OF CONSTRUCTION MANPOWER DEMAND

CHAPTER 4 LITERATURE REVIEW – DETERMINANTS OF CONSTRUCTION MANPOWER DEMAND

4.1 INTRODUCTION

Causal forecasting approach has been evaluated as appropriate and reliable to the forecasting of construction manpower demand at both project level and industry level. This chapter therefore aims to acquire a list of the determinants of construction manpower demand at the two levels. The acquisition of demand determinants involved two stages. In the first stage, extensive literature search of factors often associated with construction manpower demand was carried. They were then vetted by experienced industry practitioners in the second stage so as to obtain a comprehensive list of determinants (details of the consultation are presented in section 5.3.2). Based on the determinants identified, the availability of labour resources and relevant data sources are assessed. These findings form a crucial step for developing the construction manpower demand forecasting models.

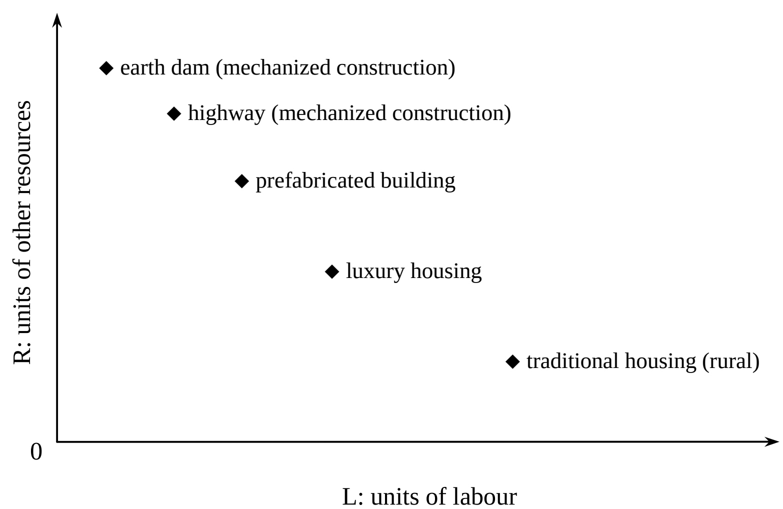
4.2 DETERMINANTS OF MANPOWER DEMAND AT PROJECT LEVEL

4.2.1 Project size

A number of researchers reveal that the specification of the manpower demand function at project level should be based on an equation taking project size (scope and scale of construction) into consideration (e.g. Lemessany and Clapp, 1978; Persad *et al*., 1995; Bell and Brandenburg, 2003). It is expected that the larger the size of the project, the more manpower required. In practice, the 'multiplier' model adopted by the Environment, Transport and Works Bureau (ETWB) explicitly exercises this relationship between construction cost and manpower requirement (Chan *et al*., 2006). Chan *et al*. (2003) also showed the strong relationship between manpower demand and project size in an analysis of 123 construction projects.

4.2.2 Project type

The occupational labour demand for a construction project is closely related to the type of project within a particular market sector because different construction projects tend to have a different product mix, capital-labour ratio and fixed cost structure (Agapiou *et al.*, 1995a; Chan *et al*., 2002). For example, some trades such as plasterers and more technical skilled workers are closely associated with new housing work, whereas scaffolders have more employment opportunities from general repair and maintenance activities (Briscoe and Wilson, 1993). The mix of skills also changes significantly, when construction shifts from piling work to the construction of the superstructure. Figure 4.1 shows a sample of construction activities, and indicates that different project types lie in different Resources-Labour (R-L) zones. For instance, building a rural traditional house certainly requires more physical labour but less plant than a prefabricated building. Clearly, project size and type are important factors that dictate the extent to which specialised skills are practised in the construction industry (Persad *et al*., 1995).



Source: Ganesan *et al*. (1996)

Figure 4.1 Construction resources used in final products

4.2.3 Construction method

The construction method of an individual project also determines the site labour input and mix of skills (Lemessany and Clapp, 1978). For instance, a residential block with traditional load-bearing external walls of brick and block requires significantly more site labour than those built by prefabricated facades. The increasing use of prefabrication, production activities off-site and the use of other engineering construction methods have caused a reduction in the demand for traditional craft skills including bricklaying, plastering and carpentry (Agapiou *et al.*, 1995a), but an increase in prefabricated elements erectors (Tang *et al.*, 2003). A recent study by Tam (2002) indicates that the high degree use of prefabricated components has resulted in an over 40% reduction of the total demand for site operatives.

4.2.4 Project complexity

Another apparent factor affecting labour demand at project level is the complexity or the design of the construction product. Gidado and Millar (1992) regarded complexity as factors hindering performance on site including technical complexity of the task, amount of the overall and interdependencies in construction stages, project organisation, site layout, and unpredictability of work on site. For instance, the design of the Bank of China building illustrated the contribution that simplified structural design could make significant savings in resource requirements. Simplified connections for the cross-braced steel truss also allowed faster erection and savings in costs. Total steel requirements were about half that used for a typical building of the same height. The reduction in the use of steel and simplified connections translated into labour-savings in the fixing and alignment of frames (Fairweather, 1986; Ganesan *et al.*, 1996). Four attributes including overall technological complexity of overall project characteristics, site physical site condition, buildability level and complexity of coordination works are considered in this study as the important factors which might have an impact on the project labour demand (Wong *et al.*, 2006a).

4.2.5 Degree of mechanisation

Degree of mechanisation and automation is also considered to critically influence the labour demand on site since labour and capital are the two types of major inputs (Ehrenberg and Smith, 2003). In general, the more the capital inputs, the less the labour required because automation and mechanised equipment tend to be manual labour saving (McConnell *et al*., 2003).

4.2.6 Management attributes

Labour requirements are also affected by contractor's management skills (Wong *et al*., 2003b). These skills can be further divided into planning, organising and controlling (Gould, 2002). Better co-ordination and utilisation of plant and labour on sites leads to reduction in manpower requirements (Ganesan *et al*., 1996). Labour saving design can be achieved through enhanced management and interfacing of different trades such as electrical and mechanical trades. Better planning of site work can avoid double handling and hence ensure efficient use of labour. For example, in laying pipes and conduits, last-minute changes due to deficiencies in design planning often result in abortive labour (Gruneberg, 1997).

4.2.7 Expenditure on E&M services

It is generally recognised that the material costs for electrical and mechanical services are unrelated to labour demand (Wong *et al*., 2003b). However these costs can be significant and represent a huge portion of the total cost in today's construction. Thus these costs should be deducted from the total project cost in order to obtain a more robust and reliable demand estimating specification.

Table 4.1 summarises the existing literature related to the determinants of manpower demand at the project level.

	Project size	Project type	Construction method	Project complexity	Degree of mechanisa-tion	Project manage-ment	E&M expenditure
McConnell *et al*. (2003)			✓		✓	✓	
Wong *et al*. (2003b)	✓	✓	✓	✓	✓		✓
Bell & Brandenburg (2003)	✓	✓					
Chan *et al*. (2003)	✓	✓					
Chan *et al*. (2002)	✓	✓					✓
Tam (2002)			✓		✓		
Tang *et al*. (2003)	✓		✓			✓	
Gruneberg (1997)	✓			✓		✓	
Huang *et al*. (1996)	✓	✓		✓		✓	
Ganesan *et al.* (1996)		✓		✓		✓	
Persad *et al*. (1995)	✓	✓					
Lemessany & Clapp (1978)	✓		✓				
Crow Maunsell (1993)	✓		✓			✓	

Table 4.1 Summary of factors affecting manpower demand at project level

Taking these factors into account, the quantitative labour demand for a construction project can be represented by the following function:

$$D_p^s = f\ \text{(COST, TYPE, PREFA, COM, MECH, MGT, E\&M)} \qquad (4.1)$$

where,

D_p^s	=	Total labour demand of trade *s* for a construction project
COST	=	Project cost indicating the size of project
TYPE	=	Project type
PREFA	=	Extent of off-site prefabrication of all construction product components
COM	=	Project complexity attributes
MECH	=	Extent of mechanisation/automation
MGT	=	Project management skills
E&M	=	Material cost on E&M services

4.3 DETERMINANTS OF AGGREGATE MANPOWER DEMAND AT INDUSTRY LEVEL

As the ‘top-down’ approach is proposed for developing manpower demand forecasting model at the industry, this section first attempts to identify the key determinants of aggregate manpower demand for the construction industry. The underlying factors driving the occupational demand are presented in the next section.

4.3.1 Construction output

A number of studies focus on estimating labour demand by pursuing the relationship between employment level and industry output (e.g. Naisbitt, 1986; Briscoe and Wilson, 1991; Ball and Wood, 1995). Briscoe and Wilson (1993) suggest that construction output is generally expected to have a positive effect on employment i.e. the higher amount of construction investment, the greater the manpower required for the industry. The estimation of future construction output can be derived by involving a series of links between construction activity and the aggregate economy. Tse and Ganesan (1997) suggest strongly that the Gross Domestic Product (GDP) tends to lead the construction flow in Hong Kong.

Latham (1994) expresses the view that government is vital to construction, and its policies directly affect the construction workload through the financing of public projects. The construction output, indeed, includes the objectives and policies set by the private and public sectors that will be implemented and formulated in the planning horizon (Uwakweh and Maloney, 1991). These objectives will result in new construction contract award and demand for construction skills.

4.3.2 Technological change

Technological change is regarded as a fundamental determinant of manpower demand at the industry level (Wong *et al.*, 2003b). Uwakweh and Maloney (1991) define technology as the systematic application and utilisation of either scientific or organised knowledge to accomplish a task. More specifically, IPRA (1991) believe that technological change in the construction industry includes improvements in material specification, product ranges, fixing and sealants, or in hand tools and equipment. Ganesan *et al*. (1996) affirm that Hong Kong has imported a substantial amount of modern construction plant and machinery during the last two decades resulting in the change of employment structure in the labour market.

These novel technological improvements with the purpose of increasing efficiency in the production process are likely to reduce the requirements for manpower (Gruneberg, 1997). For example, robots have been implemented in Japan's construction work since early 1990s, resulting in about 50% of labour requirements replaced by the automation (Cousineau and Miura, 1998; Doyle, 1997). Labour productivity in construction can be used as a proxy for the technological change as suggested by Nakanishi (2001). Rosenfeld and Warszawski (1993) also stated that the labour productivity rate could reflect the pace of technological change and the enhancement of management practices.

4.3.3 Wage level

Coming from a pragmatic viewpoint, another variant that may influence the manpower demand in the labour market is the wage level. In an open economy, high labour costs may reduce demand (Ross and Zimmermann, 1993). Ball and Wood (1995) also argue that an increase in construction wages encourages construction firms to substitute capital and pre-fabricated components for on-site labour. Ehrenberg and Smith (2003) further state that employers have incentives to cut costs by adopting a technology that relies more on capital and less on labour when wage increases. A negative relation between construction wages and employment is thus expected.

4.3.4 Factor price terms

The majority of employment models reported in the recent literature also contain factor price terms including the material price and the interest rate (Ncube and

Heshmati, 1998; Briscoe and Wilson, 1991). The interest rate coefficient is expected to be positive, given that firms substitute labour for capital as the price of capital rises. In construction, particularly, interest rates might have a more general effect on the level of demand for the sector's output. The overall impact of changing interest rates therefore depends on taking a more general macroeconomic view of the situation. This reflects the fact that as the cost of capital falls, firms are encouraged to use less labour intensive methods. However, Briscoe and Wilson (1993) argued that falling interest rates may have a positive effect on construction output. This latter effect outweighs the direct impact of interest rates, so that overall lower interest rates may result in higher employment levels in construction.

Based on the previous literature of modelling specifications for the occupational demand, the function of aggregate manpower demand for the construction industry can therefore be given by:

$$D_c = f\ (\mathrm{Q, LP, RW, FP}) \tag{4.2}$$

where

D_c	=	Total manpower demand for the construction industry
Q	=	Total construction output
LP	=	Labour productivity
RW	=	Real wage in the construction industry
FP	=	Factor price terms (material price and interest rate)

4.4 DETERMINANTS OF OCCUPATIONAL SHARE AT INDUSTRY LEVEL

4.4.1 Construction output

Cyclically rising construction output levels are expected to increase the share of some occupations at the expense of others (Briscoe and Wilson, 1993). For instance, a one percent increase in construction output might have different effects, in terms of percentage change, on employment demand amongst different occupations. Vaid (1996) also states that a change in the level of construction industry output not only affects the inter-sectoral flows of inputs and outputs with other sectors, but also affects the general employment and the for occupational distribution in construction.

4.4.2 Mixture of the industry workload

In addition to the industrial output cycle, another potential influence on occupational share is the mixture of the industry workload (Rosenfeld and Warzawski, 1993). It is generally recognised that some of the skilled trades and technicians are in higher demand when the volume of new work increases. Equally, traditional manual skills can be expected to increase their employment share when the percentage of repair and maintenance, as opposed to new building and infrastructure works, is rising. Hence, the occupational share is influenced by the fluctuations of construction output as well as the work-mix of different construction activities.

4.4.3 Technological change

The pace of technological change is also an indispensable determinant of occupational demand at the industry level (CITB, 1991). Vaid (1996) also emphasizes that the technological progress in construction industry change the skill mix and in favour of skilled manpower. The increasing use of prefabricated components in the building sector is an example showing how technology affects the construction occupational demand as mentioned in section 4.2.3. Therefore, it is critical to examine how technological alternatives influence manpower requirements and the occupational share.

Capital to Employment Index (CEI), suggested by the ROA, could be used as a technology variable for modelling occupational share. This variable represents the capital intensity of production for the sector, relating the volume of investment in equipment, transportation, and engineering work (as a measure of the stock of capital goods), to employment (as a measure of the 'structural' workforce, controlled for business cycle fluctuations) as shown by Equation 4.3.

$$CEI = INV / EMP \qquad (4.3)$$

where *INV* is investments (gross additons to fixed assets) in the construction industry, and EMP_t is the total number of employed person in the construction industry.

4.4.4 Production capacity utilisation

The actual occupational demand in the sector is also related to the production capacity available (Cörvers *et al*., 2002). Degree of capacity utilisation should therefore be considered in the occupational model which indicates specific business-cycle effects in construction. However, that variable is difficult to construct because there are difficulties in determining a sector's capacity (Dekker *et al.*, 1994). The solution has been found in a variable assumed to fluctuate in positive proportion to the degree of capacity utilisation: the value added[4] in a particular period as suggested by the Research Centre for Education on the Labour Market (ROA) in the Netherlands.

4.4.5 Time trend

In addition to the above factors affecting the occupational share, the cursory inspection of the occupational share in the local construction industry suggests that some occupations exhibit long-term trend characteristics. Studies of occupational trends of employment markets in the local construction industry have also established clear trend increases for non-manual occupations and corresponding reductions for skilled manual trades (Ganesan *et al.*, 1996; Wong *et al.*, 2006b). Therefore, it is necessary to test the occupational shares series for the significance a linear trend.

Table 4.2 shows a summary and a systematic critique of the existing literature related to the respective determinants of aggregate manpower demand and occupational share at the industry level.

[4] According to the Census and Statistics Department of the HKSAR Government, value added = gross output - value of sub-contract work rendered by fee sub-contractors - consumption of materials and supplies; fuels, electricity and water; and maintenance services - rent, rates and government rent for land and buildings - rentals for hiring machinery and equipment - other operating expenses.

	Aggregate manpower demand				Occupational share				
	Construction output	**Technological change**	**Wage level**	**Factor price terms**	**Construction output**	**Industry work-mix**	**Technological change**	**Production capacity utilisation**	**Time trend**
McConnell *et al*. (2003)		✓					✓	✓	
Wong *et al*. (2003b)	✓	✓	✓	✓	✓	✓	✓		
Cörvers *et al*. (2002)		✓			✓			✓	
EMB (2000)	✓					✓			✓
Mackenzie *et al.* (2000)	✓	✓			✓	✓	✓		
Ncube and Heshmati (1998)	✓	✓	✓	✓					
Grunberg (1997)		✓				✓		✓	
Vaid (1996)	✓				✓	✓	✓		
Ganesan *et al.* (1996)	✓	✓				✓	✓		✓
Willems (1996)		✓	✓	✓		✓	✓		
Apagiou *et al*. (1995a)	✓	✓				✓	✓		
Ball and Wood (1995)	✓		✓	✓					
Dekker *et al*. (1994)		✓			✓			✓	
Briscoe and Wilson (1993)	✓		✓	✓	✓	✓	✓		✓
Rosenfeld and Warszawski (1993)	✓	✓				✓			
Ross and Zimmermann (1993)		✓	✓						
Briscoe and Wilson (1991)	✓		✓	✓					
CITB (1991)	✓	✓				✓	✓		
Uwakweh and Maloney (1991)	✓	✓				✓			
Hamermesh (1988)	✓	✓	✓				✓		
Naisbitt (1986)	✓								

Table 4.2 Summary of factors affecting manpower demand at industry level

The proposed occupational share estimate for the construction industry of Hong Kong is represented by the following function:

$$P_s = f\ (Q, MIX, CEI, VA, TIME) \tag{4.4}$$

where,

P_s	=	Percentage share for labour demand of occupation *s*
Q	=	Total construction output
MIX	=	Mixture of construction output in different sectors
CEI	=	Capital to employment index
VA	=	Value added
TIME	=	Linear time trend variable

4.5 AN EVALUATION OF LABOUR RESOURCE DATA

Castley (1996b) stresses that manpower planning is largely concerned with the quantitative aspect of human behaviour in the aggregate as well as in the occupational classifications. Reliable labour force data and proper investment plans are therefore pre-requisites to such accurate labour models (Jayawardane and Gunawardena, 1998). Having identified the determinants of manpower demand, understanding of the extent to which the available data is disaggregated and updated is therefore vital for establishing manpower forecasting models. This section evaluates the sources and nature of the relevant data for modelling including the data series of construction employment and the identified determinants.

4.5.1 Time series data for construction employment

Employment data in construction are complex because of the wide variety of sources available, the different methodologies they use, and the significance of self-employment in the industry (Ball and Wood, 1995). There are three principal sources of information on construction employment: (i) the GHS series; (ii) the VTC series; and (iii) the C&SD series.

The GHS series

The quarterly *General Household Survey* (GHS) is a survey of Hong Kong's household living conducted by the Census and Statistics Department (C&SD). This sample survey covers about 98% of the Hong Kong resident population designed to collect detailed information of labour force characteristics including employed persons, unemployed persons and underemployed persons in accordance with the relevant economic sector. The employment data series is classified into seven broad occupational groups, namely, Managers and Administrators, Professionals, Associate Professionals, Clerks, Craft and Related Workers, Plant and Machine Operators and Assemblers, and Elementary Occupations.

The VTC series

The Vocational Training Council (VTC) publishes employment and vacancy estimates by detailed occupations for the Hong Kong construction industry. The series has been published in the biennial VTC Manpower Survey Reports specifically with the aim of determining the manpower needs of the building and civil engineering industry with a view to recommending measures to meet those needs (VTC, 2003). Despite some apparent limitations of the survey, such as lack of frequent updates, this series provides an important and comprehensive source of information on occupational changes over time in the construction sector, and include figures for all directly employed manpower and for trainees. The most recent series are based on a total of 10,822 construction sites, offices, firms and institutions in the industry, covering over 120 construction related occupations. The Electrical and Mechanical Services Training Board conducted a supplementary manpower survey to collect manpower data on electrical and mechanical (E&M) workers working on construction sites since 2001.

The C&SD series (manual workers)

The C&SD also produces construction employment and vacancy statistics on a quarterly basis, but is limited to manual workers. Data required for the compilation of employment figures are gathered from two sources: (i) the Quarterly Employment Survey of Construction Sites in the private sector conducted by the C&SD; and (ii) administrative records furnished monthly by respective Government departments for the public sector sites collected via 'Monthly Return of Site Labour Deployment and Wage Rates in the Construction Industry' (Form GF527). The employment figures collected are disaggregated by various end-uses of construction project and by trades.

Table 4.3 shows a comparison on the nature and features of the three sources of construction employment. Large discrepancies of the employment figures among these surveys were detected since they are complied for different purposes, with different collection methods, times and coverage. On the one hand, the GHS covers both employed persons working in establishments and self-employed persons, whereas the VTC survey covers only those working in establishments technically related to construction work. On the other hand, the employment statistics in construction sites compiled by the C&SD exclude minor alternations, repairs, maintenance and interior decoration works.

	VTC Manpower Survey	General Household Survey	Quarterly Report of Employment and Vacancies at Construction Sites
Frequency	Biennially	Quarterly	Quarterly
Degree of disaggregation	129 occupations and 4 broad categories	7 broad occupation categories	40 manual worker occupations
Available period	1979 – 2003	1983 – 2005 (total) 1993 – 2004 (by occupation)	1980 – 2005
Coverage of the survey	All persons employed by main contractors and sub-contractors in construction sites and offices, except those engaged in accounting, administrative and clerical jobs	Based on a sample of quarters selected scientifically from records of all permanent and temporary structures in Hong Kong. The survey thus covered about 98% of the total population of Hong Kong (including self-employed)	All manual workers engaged in private sector sites registered with the BD; public sector sites under the charge of Works Departments and Housing Department; sites under control of MTRCL, KCRC and AA. However, construction projects for village-type houses in the NT, minor alternations, repairs, maintenance and interior decoration of existing buildings are not included.
Labour types involved	Professional/ Technologist, Technician, Tradesman, Semi-skilled worker/ General Worker.	Managers and administrators, Professionals, Associate professionals, Clerks, Service workers and shop sales workers, craft and related workers, Plant and machine operators and assemblers, Elementary occupations.	Craftsmen, Semi-skilled and Unskilled workers.
Labour types excluded	Managers and Administrators, Clerks, Elementary Occupations	--	Professional and administrative personnel such as architects, engineers, surveyors, contract managers, site agents, clerk of works, site foremen and general clerical staff.
		Occupational Demand Figures in 2003	
Managers and administrators	-	18,258	-
Professionals	14,327	11,135	-
Associate professionals	27,731	32,148	-
Craft and related workers	54,616	151,814	69,954
Plant and machine operators and assemblers		10,808	
Clerks	-	15,251	-
Elementary occupations	17,632	35,921	-
Total	114,306	275,336	69,954

Table 4.3 Comparison of the construction manpower surveys

4.5.2 Key data series

In order to develop the manpower demand forecasting model at the industry level, it is necessary to link the demand to the independent variables identified in sections 4.3 and 4.4. This section presents the sources and nature of the data series for these variables, including (i) construction output; (ii) wage level; (iii) material price; (iv) bank interest rate, and (v) labour productivity.

Construction Output

Data for gross value of construction work are available from the reports on the quarterly survey of construction output issued by the C&SD. This series covers all construction establishments engaged in all new architectural and civil engineering work, as well as demolition, repair and maintenance of immobile structures. Labour-only sub-contractors are excluded from direct enumeration but their output is implicitly included in that of contractors commissioning their services.

The survey also covers the disaggregated output series analysed by *broad trade group* (further disaggregated by construction work at construction sites by (i) private sector; (ii) public sector; and (iii) construction work at locations other than sites, disaggregated by general trades and special trades[5]) and by *nature of construction activity* (further disaggregated by site (i) formation and clearance; (ii) piling and related foundation work; (ii) erection of architectural superstructure;

[5] General trades include decoration, repair and maintenance, and construction work at minor work locations such as site investigation, demolition, and structural alteration and addition work; Special trades include carpentry, electrical and mechanical fitting, plumbing and gas work etc.

and (iv) civil engineering construction). The aggregate and disaggregate output data series is maintained in the C&SD databank respectively from 1983 and 1993 onwards.

Wage level

There are several sources of information relating to the wage level in construction. The 'median monthly employment earnings in the construction industry' series was available from the GHS reports to represent the wage level in the industry (from 1980 onwards). The VTC biennial manpower survey reports also yield information on employment by monthly income range (from 1979 onwards). The sample enables series to be disaggregated according to each occupation. The C&SD also issues average daily wages of manual worker engaged in public works monthly (from 1970 onwards).

Material price

The official material price index is compiled by the Architectural Services Department (ArchSD) of the HKSAR Government, based on the average prices of material supplied by the C&SD and the Hong Kong Construction Association (HKCA) Ltd. This series applies to prime materials according to the pre-fixed weighting with all necessary adjustments to produce the current index. It is adjusted based on the Tender Price Index with the base value of 100 at the first quarter of 1970.

Bank interest rate

Two principal interest rates series are disseminated by the Hong Kong Monetary Authority (HKMA): the 'Hong Kong Dollar Interest Rates' (1 week, 1 month, 3 months, 6 months, 12 months and best lending rate) and the 'Hong Kong Interbank Offered Rates (Interest Settlement Rates)' (overnight, 1 week, 1 month, 3 months and 6 months). The Hong Kong Association of Banks (HKAB) is the source and owner of the HKD Interest Settlement Rates.

Labour productivity

There is no official productivity series published for the local construction industry. Gross construction output per man-hour was used as productivity measure. This series complies with the measurement method of labour productivity adopted by Lowe (1987) and Rojas and Aramvareekul (2003) as shown in Equation 4.5. Data for construction output, at constant (2000) market prices, were extracted from the reports on the quarterly survey of construction outputs issued by the C&SD. The median hours of work series is accessible from the GHS reports.

$$LP = \frac{Q}{EMP * H} \tag{4.5}$$

where Q is construction output in dollar; EMP is total employed person and H is median hours of work.

4.5.3 Implications for model development

A variety of relevant data has been examined. Taking into account the nature and properties of these series in terms of coverage, continuity, availability and regularity, the following implications can be drawn for this study:

i) The deployment records obtained from the GF527 offer a reliable site-based data for modelling manpower demand at project level. However, the project-based model is confined to site worker only. Additional survey is needed to collect project information to formulate project-based forecasting model (see section 5.3.2).

ii) The employment series extracted from the GHS are used for modelling total construction employment demand at the industry level primarily because the reliability and completeness of the survey. Vacancy rates acquired from the VTC biennial manpower survey reports are combined to the corresponding employment level for deriving quarterly manpower demand series. Missing values could be replaced using linear interpolation.

iii) The GHS occupational employment series are used for developing the specifications of the demand for seven broad occupations; the VTC employment data are the prime source for share analysis of detailed occupations. Because of the discrepancies of labour resource data in some occupations between the two surveys, detailed occupational analyses are confined to professional and associated professional (technician) levels.

iv) The data for key determinants of industrial manpower demand are readily accessible for analysis. Regarding the wage level, the 'median monthly employment earnings in the construction industry' obtained from the GHS offer a frequent and comprehensive data series for subsequent modelling purpose. The consumer price index is used to discount the effect of inflation to derive the real wage series in construction. Besides, the series of Three Months Hong Kong Dollar Interbank Offered Rates is selected as bank interest rate for developing forecasting model.

4.6 SUMMARY

This chapter has probed a range of factors influencing construction manpower demand at both project and industry levels from a comprehensive literature review in general and verified by experienced industry practitioners in particular. The source and nature of relevant data series have also been identified and evaluated. These two sets of knowledge are equally vital for developing the manpower demand forecasting models for this study. The identified determinants are subsequently tested and incorporated to develop the manpower demand forecasting models at project level and at industry level. The developments of the forecasting models are presented in Chapter Six and Chapter Seven respectively, following the details of the research methodology in the next chapter.

CHAPTER 5 RESEARCH METHODOLOGY

CHAPTER 5 RESEARCH METHODOLOGY

5.1 INTRODUCTION

This chapter presents the research strategy and methodology adopted to achieve the research objectives stated in the first chapter. This begins with a discussion of alternative methodologies and the rationale behind the selection of the research methodology. The research process from the literature review to data collection and empirical analysis is then stated. Particularly, the analytical techniques applied for developing the manpower demand forecasting models at both project and industry levels are justified and discussed.

5.2 RESEARCH DESIGN AND STRATEGY

Research design is the arrangement of logical sequence that connects the empirical data produced by research to the initial research questions and ultimately to its conclusions (Yin, 1989). Buckley (1976) suggested the following four research strategies:

i) *Opinion research* – If the researcher seeks the views, judgement or appraisals of other persons with respect to a research problem, he/she is engaged in opinion research (e.g. questionnaires, opinion pools, and interview).

ii) *Empirical research* – An empirical research strategy requires that the researcher observe and/or experience things for himself/herself rather than through the mediation of others (e.g. case study, field study, laboratory).

iii) *Archival research* – This is concerned with the examination of recorded facts (e.g. original documents or official files of records, publication of data by other investigators).

iv) *Analytical research* – Analytical research relies on the use of internal logic on the part of the researcher. The research has the resources required for solving the problem individually. No explicit reference to external data is necessary.

This present research covers a number of complex and inter-related issues, hence a step-by-step approach is adopted. Figure 5.1 shows the overall research design and strategy. It is based on a combination of the above research strategies in accordance with the research objectives.

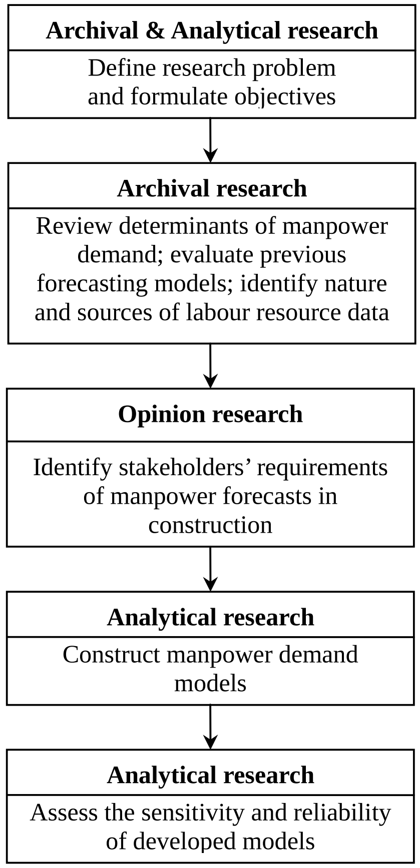


Figure 5.1 Research strategy

There is a large volume of literature on the subject of manpower planning and forecasting. Therefore archival research is used at the initial stages of the research to define the problem and formulate the objectives. The reliability of existing manpower forecasting models in Hong Kong is evaluated using analytical tools. Extensive archival research is adopted to review manpower demand determinants and various previous approaches to modelling manpower demand from relevant publications. This approach is further used to examine the nature and sources of relevant data series to facilitate the development of forecasting models.

In addition, in order to identify stakeholders' requirements of manpower forecasts for the construction industry in Hong Kong, opinion research is carried to seek the expertise from the industry practitioners. Archival and empirical research is considered inappropriate as it would not be able to cover the users' expectations and experiences of the local practitioners. Analytical research techniques are then applied to develop robust manpower demand forecasting models at project level and industry level. This strategy is adopted because forecasting models are developed via systematic analysis on the causal relationship between manpower demand and the determinants identified. Finally, verifications are conducted to test the reliability and sensitivity of the developed forecasting models.

5.3 RESEARCH PROCESS

Having decided on the appropriate research strategy, the research is undertaken in the following three main phases as previously shown in Figure 1.4:

- Phase One: literature review and evaluation of forecasting approaches;
- Phase Two: pilot study and data collection; and
- Phase Three: formulation of forecasting models.

5.3.1 Phase one: literature review and evaluation of forecasting models

Initially, the gaps in the knowledge in manpower practices were identified from a literature review. An empirical analysis was also conducted to provide evidence on the deficit of the local forecasting models by comparing the forecasts with actual manpower data. Research focus and objectives were thereby established.

A more comprehensive search of literature on labour resources management and forecasting was then undertaken to investigate issues relating to manpower planning. Relevant professional journals, books, working papers, conference proceedings and reports were reviewed. The literature search focused on:

- The context and rationale of manpower planning;
- Manpower planning practices;
- Manpower demand forecasting methodologies;
- Determinants of manpower demand; and
- Economics of labour market.

Several important findings were identified from the review of relevant literature. In particular, the worldwide manpower planning practices were acquainted as reported in Chapter Two. This forms an essential base for the study. Additionally, in order to assess the various options open, strengths and weaknesses of existing approaches for forecasting project-based and industry-based manpower demand are evaluated and detailed in Chapter Three. The aim of the review is to gain potential learning points and improvements from the most up to date knowledge to enhance the forecasting models for the Hong Kong construction industry. The most appropriate forecasting methodologies adopted in the modelling process were thereby proposed, based on (i) evaluation of the feasible forecasting approaches; (ii) the stakeholders' requirements; and (iii) the available data. Consequently, since causal model was selected as the forecasting method, the determinants driving manpower demand at the project level and industry level were identified via the literature review for subsequent model development as reported in Chapter Four.

5.3.2 Phase two: pilot study and data collection

Pilot study

In order to gain a fuller understanding of the end-users' requirements for an advanced manpower forecasting system, a series of semi-structured interviews was carried out both within and outside Government bodies. 11 participants were recruited, six of which took part in the Construction Advisory Board (CAB[6]) in assessing the development of construction manpower forecasting practice in Hong Kong. Five of the interviewees are industry practitioners who have extensive experience in manpower planning in the private sector. The general backgrounds of the interviewees are shown in Table 5.1.

A qualitative approach was adopted to analyse the requirements of manpower forecasting by various stakeholders for the construction industry in Hong Kong. The technique of thematic analysis[7] as set out by Ezzy (2002) was applied. An attempt was made to build a systematic bank of information collected from the

[6] The Construction Advisory Board is an advisory body set up under the Works Bureau. It is chaired by the Secretary for Works and its membership comprises industry representatives and representatives from concerned Government bureaux and departments.

[7] Thematic analysis is a tool to analyse patterns within the qualitative data and identify the multiple relations between different themes that make a text corpus consistent and intelligible (Forest *et al*., 2002).

interviews. The interview data and information were firstly transcribed and subsequently coded. Themes were then identified within the data without defining those categories prior to the analysis, and the results were primarily 'induced' from the data. Relationships were sought between categories by examining meaning and overlap between codes and a coding frame was devised. The findings of the analysis are presented in section 2.2.3. In addition, the factors affecting construction manpower demand identified from the review of literature were verified by the interviewees to acquire a comprehensive list of demand determinants.

Interviewees	Organisation	Position
1	Environment, Transport and Works Bureau (ETWB), HKSAR Government	Assistant Secretary
2	Architectural Services Department (ArchSD), HKSAR Government	Senior Quantity Surveyor
3	Water Supplies Department (WSD), HKSAR Government	Senior Project Manager
4	Construction Industry Training Authority (CITA)	Public Relations & Trainees Recruitment Manager
5	Provisional Construction Industry Coordination Board (PCICB)	Chairman of Working Group on Skills Development for Construction Workers
6	The Hong Kong Construction Association (HKCA)	Secretary General
7	Mass Transit Railway Corporation Limited (MTRCL)	Programming Manager
8	Kowloon-Canton Railway Corporation (KCRC)	Project Planning Engineer
9	Shui On Construction and Materials Limited	Assistant General Manager
10	China State Construction Engrg. (Hong Kong) Ltd	Project Manager
11	Able Engineering Company Limited	Site Engineer

Note: Names of the interviewees are not shown in the interests of privacy

Table 5.1 List of interviewees

Data collection for developing forecasting models

- *Project-based model*

In order to derive forecasting models for estimating project-based labour demand, labour deployment records of public works were first obtained from the Census and Statistics Department (C&SD) of the HKSAR Government. Contractors are contractually required to submit the 'Monthly Return of Site Labour Deployment and Wage Rates in the Construction Industry' (Form GF527) to the C&SD for public works and public housing projects. The records of the site workers are further broken down into 38 specific trades, reflecting the specialisation practice in the industry. Labour deployment data for projects completed between 1998 and 2002 were acquired for this study.

Subsequently a questionnaire was designed to collect the project particulars i.e. the independent variables. To prepare a valid set of questions, guideline on preparing questionnaires were studies, such as the contents, purpose and wording of the questions. A literature review and the abovementioned pilot study were also undertaken to identify the determinants of project labour demand. As a result, the key determinants of labour demand identified were measured in the questionnaire. These include (i) project cost; (ii) project type; (iii) extent of off-site prefabrication; (iv) extent of mechanisation/automation; (v) material cost on E&M services; (vi) project management skills; and (vii) project complexity attributes. All questions are of the close-ended type to provide a uniform format to facilitate forecasting mode development as shown in Table 5.2. In this study, most of the pre-coded answers were set to a nominal or ordinal scale.

Explanatory variables		Definitions/codes
1. Project type	TYPE	Dummy variable: 1=building; 0=civil
2. Final contract amount	COST	In HK$ million
3. Approximate percentage of the expenditure on mechanisation/ automation of the final contract sum	MECH	1=less then 5%; 2=6-10%; 3=11-15%; 4=16-20%; 5=21-25%; 6=26-30%; 7=31-35%; 8=36-40%; 9=41-45%; 10=46-50%; 11=more then 50%
4. Approximate percentage of the material cost on E&M services of the final contract sum	E&M	1=less then 5%; 2=6-10%; 3=11-15%; 4=16-20%; 5=21-25%; 6=26-30%; 7=31-35%; 8=36-40%; 9=41-45%; 10=46-50%; 11=more then 50%
5. Approximate percentage of off-site prefabrication of all construction product component	PREFA	1=less then 10%; 2=11-20%; 3=21-30%; 4=31-40%; 5=41-50%; 6=51-60%; 7=61-70%; 8=71-80%; 9=81-90%; 10=91-100%
6. Main contractor's overall management of the project	MGT	1=extremely ineffective; 9=extremely effective
7a. Technological complexity of overall project characteristics	COM	1=extremely simple; 9=extremely complex
7b. Complexity of the physical conditions of the construction site	COMA	1=extremely simple; 9=extremely complex
7c. The level of buildability	COMB	1=extremely low; 9=extremely high
7d. Complexity of the coordination works between the design and construction team	COMC	1=extremely simple; 9=extremely complex

Table 5.2 Structure of questionnaire and codes used for variables

Instructions are clearly stated in the questionnaire to prevent void responses. An additional pilot study was carried out to test the relevance and comprehensiveness of the questionnaires before a full-scale survey was conducted. Sound questionnaire design principles should focus on the wording of the questions; the categorising, scaling, and coding of the responses received; and general appearance of the questionnaire (Sekaran, 2003). Feedbacks from academia, industry practitioners and Government officers were incorporated to fine-tune and finalise the questionnaire (Appendix D). The contract number used by corresponding organisation is indicated on each set of questionnaires to match with that of the project list complied for subsequent follow-up purposes.

All Works Departments[8] with the support and assistance of the Environment, Transport and Works Bureau (ETWB) and the Housing Department (HD) were approached to acquire details of 75 randomly selected projects[9] from the database provided by the C&SD. Two Railway Corporations and the Hong Kong Housing Society (HKHS) were also approached to provide occupational labour records and details of 22 recently completed projects[10]. Letters indicated the objectives of the research were subsequently sent out to relevant government project officers to invite them to participate in the questionnaire survey. Follow-up telephone calls and electronic communication were undertaken where possible to elicit more detailed responses and/or provide further clarification for any unclear/ misunderstood items in the survey. Unfortunately contractor's management performance, an item included in the survey, was considered as sensitive information and could not be obtained.

Consequently 54 project data sets were received in total, giving rise to a 55.7% response rate. The quantity of distributed and completed questionnaires returned from the organisations is shown in Table 5.3. Of these 54 cases, 75.9% were civil projects including Roads and Drains, Service Reservoir, Footbridge, Geotechnical Works and Road Maintenance. The remaining one quarter (24.1%)

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[8] Electrical and Mechanical Services Department (EMSD) is exempted from this study because nil capital construction projects were found in the EMSD. It merely provides electrical, mechanical, electronic engineering and building services for government departments and public institutions in Hong Kong.

[9] As agreed with the representative of the ETWB, the number of sets of project details obtained from each Works Department was limited to 10-15 projects.

[10] Similar to the Works Departments, 10 sets of project details were requested from the two railways corporations. Additionally, HKHS agreed to provide two sets of projects details for the study.

were building works, which include education and residential development. The characteristics of the sample projects ranged from HK$2.7M to HK$1906.7M in construction cost; from 10 months to 63 months in contract period; and from 1.1 thousand man-days to 330.2 thousand man-days in site operatives requirement. All the cost values were adjusted by the Composite Consumer Price Index (CCPI) before entering for analysis. The aim was to single out price movements caused by the changes in general price levels of the economy.

Organisations	Number of questionnaires distributed	Number of valid sample	Response rate
Architectural Services Department (ArchSD)	15	11	73.3 %
Civil Engineering Department (CED)	10	2	20 %
Drainage Services Department (DSD)	8	8	100 %
Highways Department (HyD)	10	10	100 %
Territory Development Department (TDD)	10	0	0 %
Water Supplies Department (WSD)	12	12	100 %
Housing Department (HD)	10	0	0 %
MTR Corporation Limited (MTRCL)	10	9	90 %
Kowloon-Canton Railway Corporation (KCRC)	10	0	0 %
Housing Society (HS)	2	2	100 %
Total	97	54	55.7 %

Table 5.3 Distribution of the questionnaire survey

- *Industry-based model*

For the purpose of developing the industry-based manpower demand forecasting model, relevant data series, based on the determinants identified from the literature, were collected. As discussed in sections 4.3 and 4.4, these series include (i) construction employment level by occupation; (ii) job vacancy; (iii) construction output; (iv) real wages; (v) construction material price; (vi) bank interest rate; (vii) labour productivity; (viii) construction investment; and (ix) value added in construction. The data were acquired from various statistics reports issued by the C&SD of the HKSAR Government and the Vocational Training Council (VTC).

The data series were cautiously selected and examined for developing the forecasting models. An evaluation of the availability and nature of these data in Hong Kong and the implications for modelling are presented in section 4.5. Relevant data series covering 1983 to 2005 were used to develop an aggregated manpower demand model, whereas the series covering 1993 to 2005 were used to model the occupational demand.

5.3.3 Phase three: formulation of forecasting models

Phase three focuses on the development of enhanced forecasting models to predict future manpower skill requirements in Hong Kong at the project level and industry level. Future values of manpower demand are unknown and treated as random variables. Their behaviour must be linked to a statistical model in order to derive prediction distributions (Snyder *et al.*, 2004). The choice of a suitable forecasting technique however is critical to the generation of accurate forecasts.

Quantitative causal techniques are extensively applied in decision process and modelling, especially in complex problems that involve multivariables. To determine the statistical relationships between variables, multiple regression analysis is a reliable and the most widely used statistical procedure (Chatterjee and Hadi, 1988). Hence, this technique was selected to develop statistical models for forecasting the demand of labour at the project level.

At the industry level, ‘top-down’ approach with econometric techniques were selected to build the occupational demand forecasting models. Co-integration analysis, a fairly novel and advanced modelling technique, was applied to develop a long-term relationship between aggregate manpower demand and relevant variables in the construction industry. A dynamic forecasting model was then developed using vector error correction modelling (VECM) technique. Thereby the occupational share models were established using time series analysis techniques. Various tests were undertaken to validate the reliability and robustness of the developed models. In addition, sensitivity analyses were carried out to highlight the sensitivity of the construction manpower demand to the macroeconomic environment. Details of the data analysis techniques adopted for developing the respective project-based model and the industry-based model are discussed in the next section.

Based on the above-mentioned methodologies, enhanced forecasting models of manpower demand at project level and industry level are established. Conclusions are drawn for this research, followed by testing and calibration of the developed forecasting models. The research report is then formulated and guidance on the implementation of manpower forecasting and further research in this field is recommended to achieve the objectives of manpower planning.

5.4 DATA ANALYSIS TECHNIQUES FOR DEVELOPING FORECASTING MODELS

5.4.1 Project-based forecasting models

Multiple linear regression (MLR) analysis is considered the most suitable technique to examine the relationships between the independent variables and the project-based labour requirements (Bell and Brandenburg, 2003; Kao and Lee, 1998). It is undoubtedly the most widely used and versatile dependence technique, applicable in every facet of business decision-making, ranging from the most general problems to the most specific (Chatterjee and Hadi, 1988). The multiple regression technique also allows combining a number of explanatory variables to produce optimal predictions of the dependent variable. The MLR model is defined by Pindyck and Rubinfeld (1998) as:

$$\mathrm{Y}_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_j X_{ji} + \mu_i; \quad i = 1, 2, 3\ldots,\mathrm{N} \qquad (5.1)$$

where Y represents the dependent variable, $X_1, X_2, \ldots, X_\mathrm{j}$ are the explanatory variables; the parameters $\beta_1, \beta_2, \ldots, \beta_\mathrm{k}$ are the partial regression coefficients; the intercept β_0 is the regression constant; N is the size of the population; and μ is the error term.

A stepwise selection procedure was used to select statistically significant variables to be incorporated into the model. This approach allows the examination of the contribution of each independent variable to the regression model. Each variable is considered for inclusion prior to developing the equation (Hair *et al*., 1998). Data variables were added one at a time and the regression model re-run noting the changes at each step in the coefficient of determination (R^2) value and, more importantly, the significance level of variables. Only those variables with a value of p of less than 10%[11] were included in the final regression equations. De Vaus (1996) states that the coefficient (R^2) indicates how much variation in the dependent variable is explained by a group of independent variables; and the higher its value, the more powerful the model.

The data on construction cost and labour man-days displayed lognormal distributions i.e. the distribution approached the normal distribution when natural logarithm was taken. This can also examine the log linear relationship between the two variables as suggested by Chan *et al*. (2003). Not only establishing the model for estimating the total labour demand for a particular project, regression models were also developed for ten essential trades: Bar Bender and Fixer; Carpenter (Formwork); Concreter; Electrician/Electrical Fitter; Excavator; Labourer; Metal worker/General Welder; Plant and Equipment Operator (Earthmoving Machinery); Plasterer; and Truck Driver. Within the 54 sample projects, these are the principal and most demanding skill trades for a construction project, representing 80.5% of the total labour demand. The labour demand figures of these trades were also transformed to logarithm form as $\log_e(L_s+1)$ where L and s respectively indicates the quantitative labour demand (in man-days) and the specific trade. This transformation was necessary to make regression

[11] The p value i.e. 10%, is cross-referenced to the regression modelling strategy adopted by Goh (1999)

relationship linear as nil demand for some trades was observed in part of the project labour deployment records.

As part of the analysis, the Cronbach alpha reliability coefficients were also tested. Cronbach's alpha determines the internal consistency or average correlation of items in a survey instrument to gauge its reliability (Norusis, 2002). The technique was employed to examine the internal consistency among the responses in the Likert scale. The standardised Cronbach's alpha is defined as:

$$\text{Cronbach's } \alpha = (k/(k-1)*[1- \Sigma (S^2_i)/ S^2_{sum}] \tag{5.2}$$

where k is the number of items (variables), S^2_i is the variance of the i^{th} item and S^2_{sum} is the variance of the total score formed by summing all of the items (Cronbach, 1951).

Alpha coefficients range in value from 0 to 1 and may be used to describe the reliability of factors extracted from dichotomous and/or multi-point formatted questionnaires or scales (Santos, 1999). If the items making up the score are all identical and perfectly correlated, the $\alpha = 1$; if the items are all independent, then $\alpha = 0$. Therefore, the higher the score, the more reliable the generated scale is.

Formulating a reliable regression model requires a few more tests for checking its validity and reliability. Examination of residuals is an important diagnostic procedure that assists in checking the underlying assumption in regression analysis, with particular attention to those related to the error term (Montgomery *et al*., 2001). Hence, the resultant model was further tested by applying regression diagnostics, for any potential problems of (i) multicollinearity using tolerance value; (ii) heteroscedasticity by a residual analysis; (iii) normality by examining Jarque-Bera statistics; and (iv) 'influential' cases (outliers) using Studentized residual and Cook's distance (Belsley *et al*., 1980; Kenkel, 1989). The computer software, SPSS for Window (version 11.0) was chosen as the statistical tool for the project-based modelling analyses.

5.4.2 Industry-based forecasting models

'Top-down' approach was evaluated as the most appropriate forecasting tool for estimating future manpower demand for the construction industry (see section 3.3). Nevertheless, the coverage and level of disaggregation of the manpower forecasting are primarily limited to the nature of available manpower data. Consequently, the industry-based forecasting models contain three separate levels: (i) aggregate demand; (ii) broad occupations; and (iii) detailed occupations. The analysing techniques adopted for these levels are discussed as follows.

Aggregate model

Cointegration analysis and vector error correction modelling (VECM) technique were applied for forecasting the aggregate construction manpower demand. These two econometric modelling techniques are intimately related (Price, 1998). Vector error correction (VEC) is a restricted vector autoregressive (VAR) that has cointegration restrictions built into specification (Lütkepohl, 2004). The VEC framework developed by Johansen (1988) and extended by Johansen and Juselius (1990) provides a multivariate maximum likelihood approach that permits the determination of the number of cointegration vectors and does not depend on arbitrary normalisation rules, contrary to the earlier method proposed by Engle and Granger (1987).

The Johansen and Juselius's VECM framework was adopted to the manpower demand forecasting because of its dynamic nature and sensitivity to a variety of factors affecting the manpower demand, and its taking into account indirect and local inter-sectoral effects. Applying conventional VAR techniques may lead to spurious results if the variables in the system are nonstationary (Crane and Nourzad, 1998). The mean and variance of a nonstationary or integrated time series, which has a stochastic trend, depend on time. Any shocks to the variable will have permanent effects on it. A common procedure to render the series stationary is to transform it into first differences. Nevertheless, the model in first difference level will be misspecified if the series are cointegrated and converge to stationary long-term equilibrium relationships (Engle and Granger, 1987). The VEC specification allows investigating the dynamic co-movement among variables and the adjustment process toward cointegrated long-term equilibrium, a feature unavailable in other forecasting models (Masih, 1995). Empirical studies (e.g. Anderson *et al*., 2002; Darrat *et al*., 1999; Crane and Nourzad, 1998) have also shown that the VECM achieved a high level of forecasting accuracy in the field of macroeconomics.

The starting point for deriving an econometric model of aggregate manpower demand is to establish the properties of the time series measuring industry employment and its key determinants (Briscoe and Wilson, 1991). Testing for cointegration among variables was preceded by tests for the integrated order of the individual series set, as only variables integrated of the same order may be cointegrated. Augmented Dickey-Fuller (ADF) unit root tests were employed which was developed by Dickey and Fuller (1979) and extended by Said and Dickey (1984) based on the following auxiliary regression:

$$\Delta y_t = \alpha + \delta t + \gamma \; y_{t-1} + \sum_{i=1}^{p} \beta_i \Delta y_{t-i} + u_t \tag{5.3}$$

The variable $\Delta y_{t\text{-}i}$ expresses the lagged first differences, μ_t adjusts the serial correlation errors and α, β and γ are the parameters to be estimated. This augmented specification was used to test for $H_0 : \gamma = 0$ vs. $H_a : \gamma < 0$ in the autogressive (AR) process.

The specification in the ADF tests was determined by a 'general to specific' procedure by initially estimating a regression with constant and trend, thus testing their significance. Additionally, a sufficient number of lagged first differences were included to remove any serial correlation in the residuals. In order to determine the number of lags in the regression, an initial lag length of eight quarters was selected, and the eighth lag was tested for significance using the standard asymptotic *t*-ratio. If the lag is insignificant, the lag length is reduced successively until a significant lag length is obtained. Critical values simulated by MacKinnon (1991) were used for the unit root tests.

Cointegration analysis and vector error correction (VEC) model were then applied to derive manpower demand specification. The industry-based manpower model at the aggregate level attempts to link construction manpower demand to variables in equilibrium identified with economic theory. Although many economic time series may have stochastic or deterministic trend, groups of variables may drift together. Cointegration analysis allows the derivation of long-run equilibrium relationships among the variables. If the economic theory is relevant, it is expected that the specific set of suggested variables are interrelated in the long run. Hence there should be no tendency for the variables to drift apart increasingly as time goes on, i.e. the variables in the model form a unique cointegrating vector.

To test for the cointegration, the maximum likelihood procedures of Johansen and Juselius were employed. Suppose that the variables in the manpower demand function are in the same integrated order, these variables may cointegrate if there exists one or more linear combinations among them. A VAR specification was used to model each variable as a function of all the lagged endogenous variables in the system. Johansen (1988) suggests that the process y_t is defined by an unrestricted VAR system of order (p):

$$y_t = \delta + \Gamma_1 y_{t-1} + \Gamma_2 y_{t-2} + \ldots + \Gamma_p y_{t-p} + u_t \qquad t = 1, 2, 3, \ldots, T \qquad (5.4)$$

where y_t are $I(1)$ independent variables, Γ's are estimable parameters and $u_t \sim$ niid(0, Σ) is vector of impulses which represent the unanticipated movements in y_t. However, such a model is only appropriate if each of the series in y_t is integrated to order zero, I(0), meaning that each series is stationary (Price, 1998). Using

$\Delta = (I - L)$, where L is the lags operator, the above system can be reparameterised in the VEC model as:

$$\Delta y_t = \delta + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + u_t \tag{5.5}$$

where Δy_t is an $I(0)$ vector, δ is the intercept, the matrix Γ reflects the short-run aspects of the relationship among the elements of y_t and the matrix Π captures the long-run information. The number of linear combinations of y_t that are stationary can be determined by the rank of Π, which is denoted as r. If there are k endogenous variables, Granger's representation theorem asserts that if the coefficient matrix Π has reduced rank $r < k$, then there exists k x r matrices, α and β, each with rank r such that $\Pi = \alpha \beta'$ and $\beta' y_t$ is stationary. The order of r is determined by using likelihood ratio (LR) trace test statistic (Q_r):

$$Q_r = -T \sum_{i=r+1}^{k} \log(1 - \lambda_i) \tag{5.6}$$

for $r = 0, 1, \ldots, k$-1 where T is the number of observation used for estimation, λ_i is the i-th largest estimated eigenvalue and is the test of $H_0(r)$ against $H_1(k)$. The models will be rejected where Π has a full rank, i.e. $r = k$-1 since in such a situation y_t is stationary and has no unit root, thus no error-correction can be derived. If the rank of Π is zero, this implies that the elements of y_t are not cointegrated, and thus no stationary long-run relationship exists. As a result, the conventional VAR model in first-differenced form shown in Equation 5.4 is an alternative specification.

The choice of lag lengths in cointegration analysis was decided by multivariate forms of the Akaike information criterion (AIC) and Schwartz Bayesian criterion (SBC). The AIC and SBC values[12] are model selection criteria developed for maximum likelihood techniques. In minimising the AIC and SBC, the natural logarithm of the residual sum of squares adjusted for sample size and the number of parameters included are minimised. Based on the assumption that Π does not have a full rank, the estimated long-run construction manpower demand in Hong Kong can be computed by normalising the cointegration vector of manpower demand as a demand function.

While the cointegrating vectors determine the steady-state behaviour of the variables in the vector error correction model, the dynamic representation of the construction manpower demand to the underlying permanent and transitory shocks were then completely determined by the sample data without restriction. One motivation for the VECM(p) form is to consider the relation $\beta' y_t$ = c as defining the underlying economic relations and assume that the agents react to the disequilibrium error $\beta' y_t$–c through the adjustment coefficient α to restore equilibrium; that is, they satisfy the economic relations. The cointegrating vector, β are the long-run parameters (Lütkepohl, 2004).

Estimation of a VEC model proceeded by first determining one or more cointegrating relations using the aforementioned Johansen procedures. The first difference of each endogenous variable was then regressed on a one period lag of

[12] AIC = T ln (residual sum of squares) + 2k; SBC = T ln (residual sum of squares) + $k$ln(T) where T is sample size and k is the number of parameters included

the cointegrating equation(s) and lagged first differences of all of the endogenous variables in the system. The VEC model can be written as the following specification:

$$\Delta d_t = \delta + \alpha(\beta' y_{t-1} + \rho_0) + \sum_{i=1}^{p} \gamma_{1,i} \Delta y_{1,t-i} + \sum_{i=1}^{p} \gamma_{2,i} \Delta y_{2,t-i} + ...+ \sum_{i=1}^{p} \gamma_{j,i} \Delta y_{j,t-i} + u_t \quad (5.7)$$

where y_t are $I(1)$ independent variables, d is the total construction manpower demand, α is the adjustment coefficient, β are the long-run parameters of the VEC function, the $\gamma_{j,i}$ reflects the short-run aspects of the relationship between the independent variables and the target variable.

Hendry and Juselius (2000) emphasize the importance of correct specification. If the future construction manpower demand is not driven by the past values of the independent variables, it is more appropriate to model the demand separately from non-causal variables. The existence of a cointegrating relationship among the variables suggests that there must be unidirectional or bidirectional Granger causality. In this case, a VECM should be estimated rather than a VAR as in a standard Granger causality test (Granger, 1988). Sources of causation can be identified by testing for significance of the coefficients on the independent variables in Equation 5.7 individually. On one hand, for instance by testing H_0: $\gamma_{2,\mathrm{i}} = 0$ for all i, y_2 Granger weak causes construction manpower demand can be evaluated in the short run (Asafu-Adjaye, 2000). This can be implemented by using a standard Wald test. On the other hand, long-run causality can be found by testing the significance of the estimated coefficient of α by a simple *t*-test. The strong Granger-causality for each independent variable can be exposed by testing the joint hypotheses H_0: $\gamma_{2,i} = 0$ and $\alpha = 0$ for all i in Equation 5.6 by a joint F-test. Similar reasoning is possible for examining whether other variables Granger-cause the manpower demand.

Various diagnostic tests were applied to assess the adequacy and reliability of the developed models. These included the Lagrange multiplier tests (LM) for up to respectively one and forth order serial correlation in the residuals, White's test (White, 1980) for heteroscedasticity (H) in the residuals and for model misspecification, the Jarque-Bera test for normality (NORM) of the residuals (Jarque and Bera, 1980). The forecasts were also verified by comparing the projections generated from the Autoregressive Integrated Moving Average (ARIMA) model which served as a benchmark. EViews (version 3.0) was selected as the statistical tool for modelling aggregated construction manpower demand.

Occupational share model – broad occupations

The broad occupational share forecasting models were formulated using a time series regression analysis to derive the relationship between the individual occupational share and the identified determinants as reported in section 4.4. Multiple regression analysis again was used because of its capability to provide a means of objectively assessing the degree and character of the relationship between the dependent and independent variables, and thereby formulating an equation to predict the dependent variable (Gujarati, 1988). Regression analysis is also a suitable tool for revealing a trend or a long-term development in a time series. With this technique it is possible to estimate the effectiveness of the intervention taking into account any underlying trends and serial correlation (Ostrom, 1990). In addition, each significant independent variable is weighted by the regression analysis procedure to ensure maximal prediction from the set of independent variables (Hair *et al*., 1998).

Lead and lag relationships between the dependent and independent variables were anticipated as individual occupational share is influenced by the past changes in the independent variables. Therefore, a maximum lag of four quarters was used as this was considered an adequate period for the influence of a change in a factor on the occupational share to be completed. The proposed model is in the form:

$$P_s = \beta_0 + \beta_{i1}\sum_{i=0}^{4} X_{1,t-i} + \beta_{i2}\sum_{i=0}^{4} X_{2,t-i} + ...+\beta_{ij}\sum_{i=0}^{4} X_{j,t-i} + \mu_i \tag{5.8}$$

where P_s represents the percentage share for labour demand of occupation s, X_1, X_2, …, X_j are the independent variables; the parameters β_{i1}, β_{i2}, …, β_{ij} are the partial regression coefficients; the intercept β_0 is the regression constant.

Equation 5.8 was estimated using stepwise regression analysis. The variables that enter and remain in the regression equation are determined by the stepwise regression criteria (probability of F to enter = 0.10, probability of F to remove = 0.15). Using this method, few variables were selected that meet the criteria. The equations were then re-estimated using only the selected variables. This analysis allows, based on economic theory, specifying the economic relationships with the precise quantification of the lag distribution being best left to the data (Burridge *et al*., 1991).

Likewise, diagnostics tests of autocorrelation, normality and heteroscedasticity were conducted to ensure the reliability of the models. If the error term is autocorrelated, the efficiency of the ordinary least-squares (OLS) parameter estimates is adversely affected and standard error estimates are biased (Pindyck and Rubinfeld, 1998). Durbin-Watson (DW) statistics and their marginal probabilities were applied to diagnose autocorrelation. As quarterly data were used, the Durbin-Watson tests were performed for autocorrelation in the OLS residuals for orders one through four. If the DW statistics are significant, autocorrelation correction is needed. Autoregressive error model was applied to correct for serial correlation. The stepwise autoregression method initially fited a model with five autoregressive lags order and then sequentially removed autoregressive parameters until all remaining autoregressive parameters had significant *t*-tests. Various diagnostic tests were also undertaken to check the serial correlation, heteroscedasticity and normality of the residuals. The analyses involved in the occupational demand modelling were carried via SAS (version 8.0) for PC.

Occupational share model – detailed occupations

The coverage of the forecasts and the selection of forecasting methodologies depend heavily on the availability and nature of the data (Rosenfeld and Warszawski, 1993). At the detailed occupational level, since only 13 biennial data points are available for the manpower engaged in the construction industry, three non-seasonal exponential smoothing (ES) methods were applied. These include single exponential smoothing (SES), double exponential smoothing (DES) (Brown, 1959), and Holt-Winter's no seasonal method (HW) (Holt, 1957; Winters, 1960), as shown in Table 5.4. For the Electrical and Mechanical personnel working in construction sites, since only two data points are available, moving average was used for estimating their share.

ES is an effective way of forecasting when there are only a few observations on which to base the forecast (Bowerman and O'Connell, 1993). This method produces a time trend forecast, but in fitting the trend, the parameters are allowed to change gradually over time, and earlier observations are given exponentially declining weights. In general, ES methods have a proven record for generating sensible point forecasts (Gardner, 1985; Makridakis and Hibon, 2000). Each method in Table 5.4 contains a measurement equation that specifies how series values are built from unobserved components. The α and β are so-called smoothing parameters. These parameters were estimated by minimising the sum of squared errors. The best method for estimating the detailed occupation share was chosen by comparing the root mean square error (RMSE). The rates derived at broad and detailed occupational levels can subsequently be combined to the corresponding employment level to forecast the future manpower demand series.

Description	Forecasts (for all k > 0)	Smoothing method (by the following recursion)
1. Single Smoothing	$\hat{y}_{T+k} = \hat{y}_T$	$\hat{y}_t = \alpha y_t + (1-\alpha)\hat{y}_{t-1}$ where $0 < \alpha \le 1$
2. Double Smoothing	$\hat{y}_{T+k} = 2S_T - D_T + \frac{\alpha}{1-\alpha}(S_T - D_T)k$	$S_t = \alpha y_t + (1-\alpha)S_{t-1}$ $D_t = \alpha S_t + (1-\alpha)D_{t-1}$ where $0 < \alpha \le 1$
3. Holt-Winters (no seasonal)	$\hat{y}_{T+k} = a(T) + b(T)k$	$a(t) = \alpha y_t + (1-\alpha)(a(t-1) + b(t-1))$ $b(t) = \beta(a(t) - a(t-1)) + (1-\beta)b(t-1)$ where $0 < \alpha, \beta \le 1$

Table 5.4 Models for non-seasonal linear forms of exponential smoothing

5.5 SUMMARY

This chapter has introduced and justified the research design and strategy to achieve the research objectives. This research comprises three phases embracing both qualitative and quantitative analyses. Phase One aims to determine the initial observations through literature review, particularly the manpower planning context in construction, determinants of manpower demand, and strengths and limitations of the existing demand forecasting approaches. The modelling approahes for forecasting construction manpower demand are thereby proposed. Phase Two focuses on data collection for the development of occupational demand forecasting models at project level and at industry level. Phase Three primarily involves the establishment of the forecasting models applicable to Hong Kong using various data analysis tools. Multiple regression analysis was used to develop the project-based forecasting models. At the industry level, cointegration analysis and vector-error correction modelling were used to forecast aggregate manpower demand; whereas the occupational models were developed using time series analysis. The reliability and robustness of the developed models were verified by various diagnostic tests. The results of the data analyses in development and testing of project-based model and the industry-based model are presented respectively in the Chapter Six and Chapter Seven.

CHAPTER 6 FORECASTING CONSTRUCTION MANPOWER DEMAND: PROJECT-BASED MODELS

CHAPTER 6 FORECASTING CONSTRUCTION MANPOWER DEMAND: PROJECT-BASED MODELS

6.1 INTRODUCTION

Ensuring adequacy of various construction personnel is important to a construction organisation in human resources planning and budgeting (Druker and White, 1996; Persad *et al*., 1995). Government authorities and the public likewise desire to assess the number of jobs created by their investment in the public expenditure for a construction project. However, as revealed in section 3.4, the multiplier forecasting model practised in Hong Kong failed to precisely predict the project-based manpower requirements. The reason might be that the previous project-based models merely took account of the simple causal relationship between manpower demand and project expenditure/productivity rate. Other potential factors have rarely been assessed by researchers to improve the accuracy of the forecasts. In addition, the estimation of labour demand by occupation has not been adequately addressed. Hence, this study attempts to fill these gaps by developing advanced statistical models for forecasting the occupational demand at the project level.

This chapter presents the development of enhanced project-based manpower demand forecasting models. The scope of the models is first reiterated. This is followed by the research findings regarding the formulation of the forecasting models using regression analysis. The robustness and assumptions of the derived models are verified using out-of-sample projects and various diagnostic tests. The applications of the models are subsequently discussed. Lastly, limitations of the forecasting models are stated.

6.2 SCOPE OF APPLICATION OF THE MODELS

Due to the availability of labour data as discussed in section 4.5, the project-based manpower forecasting models are confined to the site operatives engaged for building and civil engineering construction works, prior to the issue of Occupation Permit (OP) or Completion Certificate or equivalent. The trade classes of construction manpower are demarcated in line with the trade classification in the 'Monthly Return of Site Labour Deployment and Wage Rates in the Construction Industry' (Form GF527) issued by the Environment Transport and Works Bureau (ETWB). This study covers the following market sectors in the construction industry of Hong Kong:

i) Public Capital Works – The public works under the ETWB are further classified into building and civil engineering. The labour returns were collected from the Architectural Services Department, Civil Engineering Department, Drainage Services Department, Highways Department and Water Services Department.

ii) Quasi-government Bodies Capital Works – The construction projects of residential buildings, non-residential buildings and civil engineering work under the quasi-government agencies including the Housing Society (HS), MTR Corporation Limited (MTRCL) and Kowloon-Canton Railway Corporation (KCRC).

A total of 11 forecasting models are developed for the total project labour demand and ten essential trades: Bar Bender and Fixer; Carpenter (Formwork); Concreter; Electrician/Electrical Fitter; Excavator; Labourer; Metal worker/General Welder; Plant and Equipment Operator (Earthmoving Machinery); Plasterer; and Truck Driver.

6.3 FORMULATION OF MODELS

The factors affecting the demand for project-based manpower were initially identified from the literature review and verified by industry practitioners as discussed in section 4.2, these factors include project size (scope and scale of construction), project type, construction method, project complexity, degree of mechanisation, management attributes, and expenditure on electrical and mechanical services. The independent variables shown in Table 5.2 were incorporated and tested to develop forecasting models to estimate the project-based labour demand using multiple linear regression (MLR) analysis. With the intention of utilising as many sample as possible to build the forecasting model and to facilitate effective validation, 50 out of the 54 samples projects formed the modelling data set, while the remaining four sets of project data were randomly selected and used to evaluate the forecasting performance of the models.

Cronbach alpha reliability (the scale of coefficient) measures were examined to verify the internal consistency of the responses under the following variables: the percentage of expenditure on mechanisation/automation; the percentage of expenditure on E&M services, the percentage of prefabrication; and the four project complexity attributes. The Cronbach's coefficient alpha is 0.6227 (*F* statistics = 39.0054, $p < 0.0001$), indicating that the scale used for measuring these factors is reliable at the 5% significance level.

From applying stepwise procedures available in SPSS (version 11.0), the detailed regression results for the total project labour demand are presented in Table 6.1. The estimated regression equation for total project labour demand is:

$$\begin{aligned}\log_e D_{\text{total labour demand}} &= 6.539 + 0.884 \log_e \text{final contract amount in HK\$M} \\ &\quad - 0.092 \text{ overall project technologically complexity} \\ &\quad + 0.059 \text{ complexity of the physical site conditions} \\ &\quad + \text{project type (0 for civil projects; } -0.178 \text{ for building projects)}\end{aligned} \quad (6.1)$$

Variable		Regression coefficient	*t*-statistic	Prob > |*t*|	Tolerance
INTERCEPT***		6.539	38.645	0.000	-
$\log_e$ COST***		0.884	28.727	0.000	0.852
COM***		– 0.092	–3.280	0.002	0.735
COMA**		0.059	2.335	0.024	0.765
TYPE*	Building	–0.178	–1.713	0.094	0.924
	Civil	0	-	-	-

Regression equation characteristics:

R^2 = 0.953	s = 0.3016	DW = 2.109
Adj. R^2 = 0.949	F(4,45) = 230.399	p = 0.000
N = 50	NORM = 0.770	

Note: *** *t*-statistic significant at .01 level; ** *t*-statistic significant at .05 level; * *t*-statistic significant at .1 level; COST, final contract amount, COM, technological complexity of overall project characteristics; COMA, complexity of the physical conditions of the construction site; TYPE, project type; s, sum of squared error; DW, Durbin-Watson statistic; N, number of sample; NORM, Jarque-Bera test for normality of the residuals.

Table 6.1 Regression estimates of total labour demand

The regression model produces an estimate of total labour demand in man-days with respect to the CCPI based on Oct. 1999 – Sept. 2000 issued by the Census and Statistics Department (C&SD). The results from the best-fit run of multiple regression analysis for each project show a p-value of less and 0.10 and R^2 values of 0.95. This indicates that 95% of the variation in total labour demand can be explained by this equation, implying that the equation is a good-fit and robust model. The values of *t*-statistics reveal that the total project cost is the most important variable in determining the overall labour demand for a construction project. This confirms the strong and positive relationship between labour demand and project size as noted by a number of researchers (e.g. Bell and Brandenburg, 2003; Chan *et al*., 2003; Persad *et al*., 1995).

In addition, the labour demand is also significantly influenced by overall project complexity, followed by site condition complexity, and project type. This is consistent with the determinants as identified by Agapiou *et al*. (1995a) and Ganesan *et al*. (1996). It is interesting to note that the project complexity is inversely influencing labour demand i.e. the more complex the project, the less labour required. One possible but profound reason may be that complex projects require more mechanisation and capital input than a relatively labour-intensive project as suggested by McConnell *et al*. (2003).

Analogous to the modelling approach for total labour demand, regression equations were derived for the quantitative demand of the ten selected labour trades. Among the 50 sample projects under scrutiny, the variables included in the equations are presented in Table 6.2. Details of the regression results are reported in Appendix E. The regression analysis identifies that the construction cost is still the most significant determinant of demand for specific skills, which appears in all regression equations of labour demand at 1% significance level. It was also found that project type has an important role to determine the labour demand for a number of skill trades. These finding echoes previous forecasting models developed by Chan *et al*. (2002) and Persad *et al*., (1995), incorporating project cost and project type as important predictors of project-based labour demand. The derived equations indicate that building projects require more metal workers/general welders, plasterers and excavators, but fewer plant & equipment operators, labourer and truck drivers as compared with civil engineering projects.

Labour Trade	Regression Equations			R^2	Adj. R^2	Sig. of F	NORM
Bar Bender & Fixer (N=49)	$\log_e(L_{bar\ bender}+1)$	=	$0.169 + 1.429 \log_e COST^{***} - 0.337\ COMB^{**} + 0.333\ COMC^{**} - 0.540\ E\&M^{***} + 0.368\ MECH^{*}$	0.708	0.674	20.871***	2.5468
Carpenter (Formwork) (N=47)	$\log_e(L_{carpenter}+1)$	=	$3.758^{***} + 1.031 \log_e COST^{***} - 0.174\ PREFA^{***} + 0.116\ COMC^{***} - 0.099\ COMA^{**} - 0.118\ E\&M^{**}$	0.929	0.920	106.568***	1.0043
Concreter (N=50)	$\log_e(L_{concretor}+1)$	=	$2.495^{**} + 1.106 \log_e COST^{***} - 0.428\ COM^{***}$	0.434	0.410	15.409***	1.5152
Electrician/ Electrical Fitter (N=50)	$\log_e(L_{electrician}+1)$	=	$2.251 + 0.832 \log_e COST^{***} - 0.479\ COMA^{**} + 0.382\ COMB^{*} + 0.493\ MECH^{**}$	0.335	0.276	5.670***	2.3458
Excavator (N=50)	$\log_e(L_{excavator}+1)$	=	$0.815 + 0.878 \log_e COST^{***} - 0.494\ COM^{**} + TYPE^{**}$ (0 for civil; 2.099 for building)	0.498	0.473	17.136***	0.5105
Labourer (N=50)	$\log_e(L_{labourer}+1)$	=	$6.371^{***} + 0.772 \log_e COST^{***} - 0.119\ MECH^{**} + TYPE^{**}$ (0 for civil; – 1.017 for building)	0.871	0.863	103.740***	0.8746
Metal worker/ Welder (N=50)	$\log_e(L_{m.worker}+1)$	=	$0.0604 + 1.208 \log_e COST^{***} + TYPE^{*}$ (0 for civil; 1.314 for building)	0.511	0.490	24.583***	1.6297
Plant & Equipment Operator (N=48)	$\log_e(L_{plant\ op.}+1)$	=	$3.286^{***} + 0.990 \log_e COST^{***} - 0.262\ PREFA^{***} + TYPE^{***}$ (0 for civil; – 2.047 for building) $+0.168\ COM^{**} - 0.195\ E\&M^{*}$	0.807	0.784	12.416***	0.3090
Plasterer (N=50)	$\log_e(L_{plasterer}+1)$	=	$2.395^{*} + 0.812 \log_e COST^{***} - 0.444\ COMA^{**} + TYPE^{***}$ (0 for civil; 3.708 for building)	0.518	0.487	16.479***	1.3399
Truck Driver (N=49)	$\log_e(L_{truck\ driver}+1)$	=	$3.192^{***} + 0.632 \log_e COST^{***} + 0.275\ COMB^{**} + TYPE^{***}$ (0 for civil; – 6.096 for building)	0.721	0.702	38.706***	3.9913

Note: *** *t*-statistic significant at .01 level; ** *t*-statistic significant at .05 level; * *t*-statistic significant at .1 level; N, number of sample projects (cases fall outside the range of 3 standard deviations are designated as influential observations and excluded); COST, final contract amount; TYPE, project type; PREFA, degree of off-site prefabrication of all construction product component; MECH, degree of mechanisation/ automation; E&M, material cost on E&M services; COM, technological complexity of overall project characteristics; COMA, complexity of the physical conditions of the construction site; COMB, level of buildability; COMC, complexity of the coordination works between the design and construction team; NORM, Jarque-Bera test for normality of the residuals.

Table 6.2 Regression equations derived for the demand estimation of the ten selected trades

The regression equations also reveal that different combination of complexity attributes, including physical site condition, buildability level and complexity of coordination works, contributes significantly to individual site operative demand. It is found that the more complex the project, the more plant & equipment operators but less excavators and concretors are required. It is also worthwhile to note from the equations that the higher level of buildability, the less demand for bar bender & fixer, electrician/electrical fitter and truck driver. In addition, the more complex the coordination works between the design and construction team, additional carpenters are needed for a construction project.

The findings of the regression equations also suggest that the expenditure on E&M services has an inverse impact to the demand particularly for bar bender & fixer, carpenter (formwork), and plant & equipment operator. Besides, more bar bender & fixer and electrician/ electrical fitter, but less labourer are required when expenditure of mechanisation/automation increases. This asserts the argument that utilising mechanised equipment may save unskilled manual labour as stated by McConnell *et al*. (2003). Additionally, it is realised that the demand for carpenter (formwork) will be reduced if more prefabrication components are used in a project. This echoes the statement suggested by Agapiou *et al*. (1995a) that activities off-site have caused a reduction in the demand for traditional craft skills. The equation for plant operator also indicates that the overall demand for this trade will be diminished, when the degree of off-site prefabrication increases, ceteris *paribus*.

6.4 MODEL VERIFICATION

Various diagnostic tests were performed to verify the reliability of the forecasting models. The results of the *F* tests verify that the specifications of the regression equations are adequate and significant. The multi-collinearity problem has been checked using the tolerance collinearity statistics among the independent variables in each of the regression model equations. All tolerance values are larger than 0.01, indicating no multi-collinearity problem is posed. The influential cases (outliers) have been detected through an 'influence analysis'[13] following the methodology suggested by Chan and Kumaaswamy (1999), and consequently excluded during the derivation of the respective model equations. Jarque-Bera statistics were examined to test normality of the residuals of each regression equation as shown in Tables 6.1 and 6.2. If the residuals are normally distributed, the Jarque-Bera statistics should not be significant (QMS, 2000). The results of the residual analysis indicate that all the probability values of the normality test are not significant. In addition, residuals variance was scrutinised to inspect the existence of heteroscedasticity.

Figure 6.1 shows a residual plot for the total labour demand estimation model. It reveals that the residuals are randomly scattered in a band clustered around the horizontal line through 0. Similar patterns were found for other occupational labour demand estimation models. Hence, it can be interpreted that the

[13] Influential analysis attempts to exclude the influential observation that is inappropriate representation of the population and substantially different from the other observations. Following the recommendations given by Hair *et al* (1998), those cases fall outside the range of 3 standard deviations are designated as influential observation and excluded for this study.

assumption of homogeneity of variance was met. These diagnoses demonstrated that, in general, the basic assumptions underlying the multiple regression analysis were not violated.

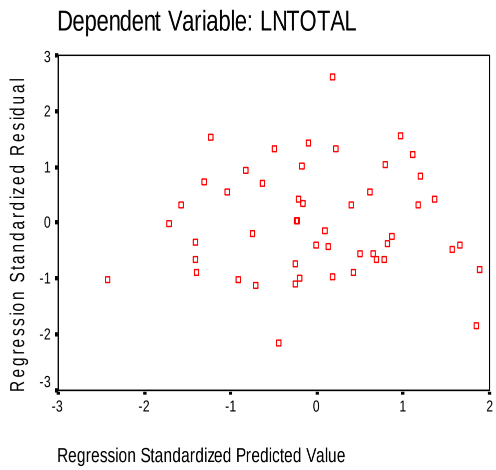


Figure 6.1 Residual plot of the dependent variable $\log_e$ total labour demand

To further test the validity of the model, the predicted values of labour demand computed from regression equations are compared to actual labour demand, using four out-of-sample project records. The results of the comparison are shown in Table 6.3. The mean absolute percentage error (MAPE) of the estimation of total labour demand is found to be 10.14%, which marginally falls above the general acceptable limit of 10% (Goh and Teo, 2000). The MAPEs of the demand estimation for the selected trades range from 8.12% (for labourer) to 22.27% (for electrician), giving the MAPE of the ten trades as 14.84%. It is not surprising to observe that the prediction error for specific trade is higher than that for the total labour demand, primarily due to the variation of specific skill needs for a unique construction project. However, the result of the evaluation confirms that the forecasting performance of the developed models is reasonably good and superior to that of the current model adopted by the Environment, Transport and Works Bureau (ETWB) which yields a MAPE of 21.16% (Wong *et al*., 2005a).

	Project 1			**Project 2**		
	Projected	Actual	Percentage Error	Projected	Actual	Percentage Error
Total	81241	87294	-6.93%	76614	89040	-13.96%
Bar Bender & Fixer	6181	8110	-23.79%	17285	15287	13.07%
Carpenter	1465	1560	-6.06%	1005	1152	-12.73%
Concreter	1598	1199	33.25%	1397	1567	-10.84%
Electrician/ Electrical Fitter	5675	7868	-27.87%	4789	4515	6.07%
Excavator	1559	1816	-14.15%	7189	8842	-18.69%
Labourer	12506	14327	-12.71%	19856	22025	-9.85%
Metal worker/ General Welder	3322	2831	17.34%	4832	4734	2.07%
Plant & Equipment Operator	1571	1394	12.71%	2748	2739	0.32%
Plasterer	4489	5255	-14.57%	30	0	-
Truck Driver	6	0	-	2366	2131.4	10.99%
	Project 3			**Project 4**		
	Projected	Actual	Percentage Error	Projected	Actual	Percentage Error
Total	2936	2724	7.78%	220824	250606	-11.88%
Bar Bender & Fixer	12	15	-20.16%	34441	38630	-10.84%
Carpenter	203	185	9.84%	25153	22246	13.07%
Concreter	23	24	-3.32%	2054	1535	33.80%
Electrician/ Electrical Fitter	50	46	8.19%	1596	1436	11.17%
Excavator	1	0	-	16148	18988	-14.96%
Labourer	1834	1691	8.43%	47185	46498	1.48%
Metal worker/ General Welder	87	73	18.84%	2992	2378	25.83%
Plant & Equipment Operator	158	193	-18.06%	26349	29538	-10.80%
Plasterer	11	0	-	41	0	-
Truck Driver	168	361	-53.57%	4666	4563	2.25%

Note: $\text{MAPE}_{\text{total labour demand}}$ = 10.14 %; $\text{MAPE}_{\text{labour demand by occupation}}$= 14.84 %

Table 6.3 Evaluation of labour demand forecasts

6.5 DISCUSSION OF THE RESULTS

6.5.1 Applications of the models

The closeness of fit in both in- and out-of-samples between the predicted and actual labour demand provides sound evidence for the model usefulness and reliability for determining quantitative demand for project-based labour. The estimation equations can serve as objective and convenient tools for predicting promptly the total labour demand and the demand of essentials trades for a construction project, from limited project information at the initial stage. The forecasts also provide solid information for human resources planning and labour cost estimations.

Construction organisations such as contractors and consultants could gain benefits from formulating and reinforcing their planning and monitoring from the labour demand estimates. The model developed may replace the current practice of estimation based mainly on the individual's experience and relative unreliable estimation method. The derived equations also serve as an important benchmark for future research which studies the manpower forecasting and labour productivity at the project level. As long as the construction sector in any particular country adopts contract forms that allow for periodic payments to the contractors, and requires the keeping of some forms of labour records, this model could be easily adopted and adapted by their construction authorities.

As pointed out in section 3.4, inaccurate estimations of labour demand generated from the previous multiplier model might be due to the plausible assumption which is based solely on the relationship between the labour demand and the construction cost (Wong *et al*, 2005a). The multiple regression analyses of this study demonstrate that the accuracy and reliability of the labour demand prediction model can be improved by incorporating additional significant variables. Yet the identification of other less significant variables should not be overlooked. An appreciation of the relative strengths of these variables (in terms of their influence on the corresponding dependent variables) has proved to be important to forecast the project-based labour demand.

It was noted that because of the changes in market situations and other uncertain factors, the actual contract value is not always the same as the original estimate. Actual project values are usually lower than the original estimates. Since the calculation of labour requirements is largely based on the estimated expenditure, it is necessary to account for this discrepancy. Based on the research work by Chan *et al*. (2002), a regression analysis was conducted to identify the relationship between the original estimate and the actual contract value using data from 453 contracts between 2001 and 2002. The regression through the origin with zero constant was performed for two different project types, namely, building, and civil engineering works. The results of the analysis are shown in Table 6.4. This provides an indicative reference for the estimates of project expenditure for the purpose of forecasting labour requirements.

	2001 – Building works	2001 – Civil works	2002 – Building works	2002 – Civil works
Contract cost adjustment factor	0.934	0.673	0.893	0.811
N	122	208	43	80
R^2	0.935	0.955	0.989	0.983
Significance	0.000	0.000	0.000	0.000

Notes: N - number of projects; Contract cost adjustment factor - the ratio between actual awarded contract values to the original engineers' estimate. It measures the degree of deviation of the awarded values from the estimate.

Source: Chan *et al*. (2002)

Table 6.4 Summary table showing the trend of the cost adjustment factors for building and civil works for the years 2001 and 2002

With the aid of the labour demand estimation equations and the cost adjustment factor, the relevant authorities can assess the number of jobs created by their investment in public expenditure. The labour requirement (in man-days) computed by the equations can be translated into the number of jobs created by substituting into Equation 6.2:

$$\text{Number of jobs created} = \frac{\text{Total labour requirements (in man-months)}}{\text{Project duration (in months)}} \qquad (6.2)$$

The number of jobs created in a project is defined as the equivalent number of persons engaged full-time throughout the whole project period. It represents the equivalent number of workers to be engaged throughout an individual total year. Given the recent severe unemployment problem encountered in the construction industry, the Government could apply this model to check and compare the degree of contribution made to job availability by various types of forthcoming public works projects.

6.5.2 Limitations of the models

Although the models generate some useful and statistically valid results, it is acknowledged that the models are subject to the following limitations.

i) The predictions of the model may at times be imprecise, unless viewed in the context of the parent database. Caution has to be exercised in respect of the magnitude of the possible error in the prediction compared to the standard deviation of the dependent variable, as this suggests a measure of the reliability that can be placed in the forecasts.

ii) Every observation in the original data set made an important contribution to the regression fit of the final model equations. As a result, any inaccurate project information or labour deployment records could have caused distortion in the model and the forecasting performance. However, influential analysis of the model helped to identify and exclude such influential cases to overcome this kind of problem.

iii) The model must be reviewed and updated from time to time in order to incorporate any innovations or marked changes in the areas of design, technology, construction method, which may affect the labour requirements and the categorisations. It is therefore advisable to expand the database on a regular basis and hence enhance its predictive accuracy.

iv) The results were derived from a sample of 50 projects, which may not be sufficient to develop meaningful regression models for all project and labour categories.

v) The model has a time lag for changes of, *inter alia*, technology mix, as well as legislation. For example, legislation on caisson piling has dramatically changed the types of labourers employed and thus the regression coefficient. Such changes can be reflected by constantly updating the database and subsequently the regression equations.

6.6 SUMMARY

This chapter has presented the derivation of advanced statistical models for forecasting labour demand for a construction project. A review of the relevant literature and a pilot study firstly sought a set of factors affecting project-based labour demand. An investigation survey was then administered to acquire these identified factors from various Government Works Department and quasi-government bodies. Consequently, labour records and project information of 54 construction projects were received for data analysis. Data sets from 50 projects were used to develop the labour demand prediction models, by applying multiple regression analysis. In total, 11 project-based forecasting models were developed for estimating total labour demand and ten essential trades. The models were then verified by various diagnostic tests and comparing the predicted values with the out-of-sample actual values. The results of the validation and diagnostic tests confirm the forecasting models to be robust and reliable.

This study provides a series of algorithms and models for predicting construction project labour requirements as functions of labour demand determinants. The results indicate that project total labour demand depends on a cluster of variables related to the project characteristics including construction cost, project complexity, physical site condition, and project type. In addition, project cost and project type have an important role in determining the occupational labour requirements. Complexity attributes, expenditure on E&M and mechanisation also significantly influence the demand for a number of individual labour trades.

The forecasting models provide practical and advanced tools for contractors and consultants to predict the reasonable labour required for a new construction project at the initial stage, which are valuable to facilitate human resources planning and budgeting. The Government could also assess the number of jobs created by their investment in public expenditure. The equations serve as an imperative benchmark for future research on fields of project-based manpower forecasting.

CHAPTER 7 FORECASTING CONSTRUCTION MANPOWER DEMAND: INDUSTRY-BASED MODELS

CHAPTER 7 FORECASTING CONSTRUCTION MANPOWER DEMAND: INDUSTRY-BASED MODELS

7.1 INTRODUCTION

In the absence of manpower forecasting, rigorous fluctuations of the construction output cycle may result in severe labour shortages and surpluses (Jayawardane and Gunawardena, 1998). A reliable set of industrial manpower demand forecasts is therefore important for manpower planning in construction. Although econometrics modelling for predicting manpower demand has been practised in many countries, little was applied in the construction industry. In addition, the existing manpower prediction models have proved to be inadequate in providing accurate forecasts. The development of a more robust forecasting model, with the availability of advanced econometric modelling techniques and sufficient time series data, would therefore be an advantage. Hence, one of the key objectives of this study is to develop advanced industry-based manpower demand forecasting models for the construction industry of Hong Kong. The industry-based models are developed based on the ‘top-down’ approach at three separate levels: (i) aggregate manpower demand; (ii) broad occupations; and (iii) detailed occupations as shown in Figure 7.1.

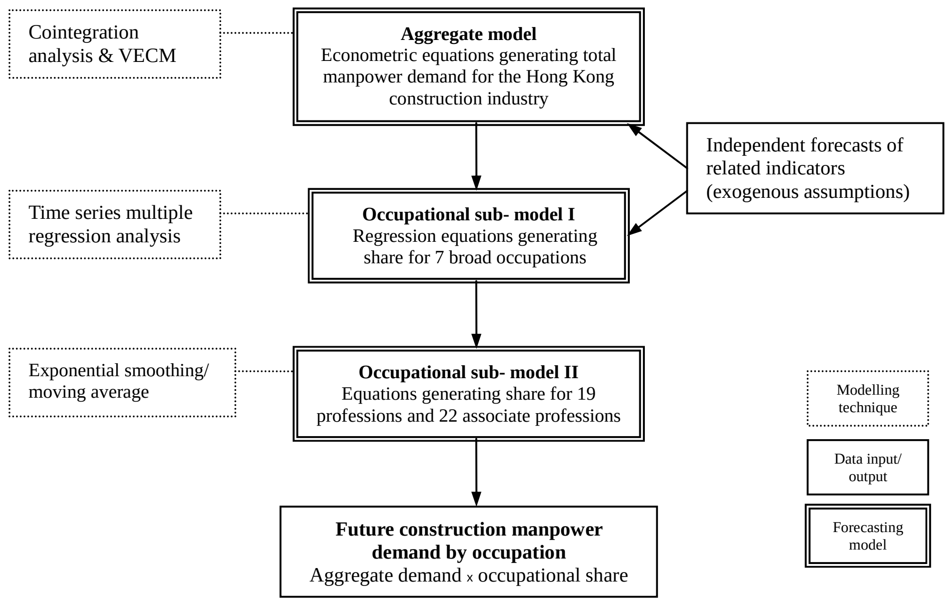


Figure 7.1 The proposed manpower demand forecasting model for the construction industry

The forecasting model at the aggregate level is established by applying the cointegration analysis and the vector error correction modelling (VECM) technique. Upon the completion of the forecasting model for the aggregate construction manpower demand, models are established to estimate the demand for specific occupation, expressed as a percentage of total construction manpower demand. The broad occupational demand forecasting model is formulated from a separate set of regression equations. Lastly, the shares of detailed occupations are estimated using exponential smoothing and moving average. The short- to medium-term occupational demand can thereby be derived by combining the occupational shares with the projected level of manpower demand at the upper level.

The detailed development of the industry-based manpower demand forecasting models is presented in this chapter. The explicit scope of the forecasting models is given first. The formulation and testing of the forecasting models at the three levels are then presented separately. Lastly, the applications and limitations of the forecasting models are discussed.

7.2 SCOPE OF APPLICATION OF THE MODELS

The industry-based models are derived primarily for the construction industry of Hong Kong. The industry embraces the activities of building construction, civil engineering, plumbing, electrical wiring, air-conditioning installation and repair (HKCSD, 2005). The forecasting model for aggregate industrial manpower demand covers all occupations involved in the abovementioned construction activities in Hong Kong.

In accordance with the nature of the available data evaluated in section 4.5, two separate levels are involved in modelling the trends of occupational share: (i) broad occupational level and (ii) detailed occupational level. According to the classification provided by the Census and Statistics Department (C&SD), the forecasting model at the broad occupational level embraces seven categories of construction personnel, namely, Managers and Administrators, Professionals, Associate Professionals, Clerks, Craft and Related Workers, Plant and Machine Operators and Assemblers, and Elementary Occupations. Descriptions of these occupations are described in Appendix B.

The evaluation of manpower statistics also found considerable discrepancies between the corresponding data sets used for estimating shares of broad occupations and detailed occupations; thus the detailed occupational analysis was confined to the professional and the associate professional occupations. This is also justified by the fact that it is more meaningful and valuable to provide forecasts of manpower demand at these levels, since it takes years to properly train a skilled technician or professional when demand increases. In addition, skill mismatches at higher occupational levels are more costly than those at operative levels. As a result, the analysis at the detailed occupational level is confined to 19 professional and 22 associate professional occupations. Descriptions of the occupations can be found in the *Manpower Survey Report of the Building & Civil Engineering Industry* and the *Manpower Statistical Report of the Supplementary Survey on E&M workers Working in Construction Sites* issued biennially by the Vocational Training Council (VTC). Nevertheless, more comprehensive forecasts should be made once data are available.

7.3 AGGREGATE MANPOWER DEMAND MODEL

This section presents the model development for forecasting the aggregate construction manpower demand using an econometric modelling approach as detailed in section 5.4.2. Stationary tests are first undertaken to determine the integrated order of the series. Following the tests, the cointegrating relationship for the aggregate manpower demand and its determinants is examined. Based on the cointegration vector determined, the forecasting model is then derived using VECM. The robustness and predictability of the developed model are verified against various diagnostic tests. The predictions generated from the model are also compared with the actual manpower demand figures. Sensitivity of the derived model and implications of the findings are also discussed.

The determinants of aggregate construction manpower demand identified from the literature include (i) output of the construction industry (*Q*); (ii) real wage in construction (*RW*); (iii) material price in construction (*MP*); (iv) bank interest rate (*BR*); and (v) labour productivity (*LP*) (see section 4.3). Relevant data of these determinants were collected from the C&SD. All variables were first transformed to their natural logarithms except the interest rate which was transformed as $\log_e(1 + BR)$ for stationarity required for modelling purpose. The coverage of these series of data spans from the first quarter of 1983 to the third quarter of 2005, giving a total of 91 data points. The first 80 quarterly records were used for training and developing the model, while the remaining 11 data points served as an independent dataset for testing and evaluating the prediction in the *ex post* forecasting period[14].

[14] Pindyck and Rubinfeld (1998) have classified economic forecasts into three types as follows:

1. *ex post* simulation - the values of dependent variables are simulated over the period in which the model was estimated, i.e. the in-sample period;
2. *ex post* forecast - in which the model is simulated beyond the estimate period, but not further than the last date for which the data is available;
3. *ex ante* forecasting - by which forecasts are made beyond the last date for which data is available into the future.

7.3.1 Unit root tests

ADF tests were initially conducted to determine the integrated order of the relevant data series. Table 7.1 reports the results of the unit root tests. These statistics indicate that a unit root can be rejected for the first difference but not the levels for all variables at the 5% significance level. Thus, the construction manpower demand, construction output, real wage, material prices and the construction labour productivity are integrated of order one i.e. $I(1)$ series. It is thus justified to test the long-term relationship among these variables using cointegration analysis.

Variable	Test statistics	Critical values	Variable	Test statistics	Critical values
D	-3.1061 [C,T,4]	-3.4696	$\Delta\ d$	-3.0189 [3]*	-1.9446
Q	0.3962 [8]	-1.9449	$\Delta\ q$	-3.8564 [3]*	-1.9446
RW	-1. 8632[C, 3]	-2.8996	$\Delta\ rw$	-8.0729 [2]*	-1.9445
MP	-2.2719 [C, 1]	-2.8986	$\Delta\ mp$	-3.8595 [C, T, 6]*	-3.4721
BR	-1.5576 [2]	-1.9445	$\Delta\ br$	-8.6395 [1]*	-1.9445
LP	-0.2272 [2]	-1.9445	$\Delta\ lp$	-8.8544 [1]*	-1.9445

Note: d, $\log_e$ of manpower demand; q, $\log_e$ of construction output; w, $\log_e$ of real wage; br, $\log_e$ (1+ interest rate); lp, $\log_e$ of labour productivity. Δ is the first difference operator. The content of the brackets [·] denotes constant, trend and the order of augmentation of the ADF test equation, respectively; * Rejection of the null at the 5% significance level.

Table 7.1 ADF unit root tests

7.3.2 Cointegration tests

Given the results of unit roots, Johansen's techniques were used to test for cointegration between the variables within a VEC model as specified in Equation

5.5. In implementing the Johansen procedure, it was assumed that series *y* has linear trends but the cointegrating equations have an intercept. This option is based on the proposition that long-run equilibrium in manpower demand probably has no significant trend. The omission of the trend term is also justified by the result of testing the significance of this term in the cointegrating relation. In addition, based on the smallest AIC and SBC values, the lag-length was selected as five and the results of the cointegration tests are reported in Table 7.2. The trace statistics indicate that there is not more than one cointegrating relation, while the test rejects $r = 0$ for the alternative that $r = 1$ at the 5% significance level. It is therefore concluded that one cointegration relation exists among the selected variables, i.e. $r = 1$.

Trace statistics			**Critical values**		
H_0	H_A	Trace	99%	95%	AIC
$r = 0$	$r = 1$	115.2070	103.18	94.15	-18.91
$r \leq 1$	$r \geq 2$	67.7633	68.52	76.07	-19.23
$r \leq 2$	$r \geq 3$	41.3637	47.21	54.46	-19.26
$r \leq 3$	$r \geq 4$	23.2504	29.68	35.65	-19.18

Note: Variables *d, q, rw, mp, br, lp*, Maximum lag in *VAR* = 5
Critical values are taken from Osterwald-Lenum (1992)

Table 7.2 Johansen cointegration trace test

By normalising the cointegration vector of manpower demand as a demand function, the estimated long-run construction manpower demand in Hong Kong implied by the Johansen estimation is given by Equation. 7.1, with absolute asymptotic *t*-ratios in parentheses.

$$d = -0.6263 + 1.2843q + 0.8063rw - 0.4137mp - 0.0169br - 0.7665lp \qquad (7.1)$$

$$(13.3587) \quad (3.7474) \quad (3.1939) \quad (1.5549) \quad (8.1454)$$

where d is $\log_e$ of manpower demand; q is $\log_e$ of construction output; w is $\log_e$ of real wage; br is $\log_e$ (1+ interest rate); and lp is $\log_e$ of labour productivity.

The results show that the long-run equilibrium equation is valid given that the independent variables contribute significantly to the cointegrating relationship at the 5% significance level. It reveals that the construction output and labour productivity have a strong influence on the construction manpower demand in the long-run. The coefficient estimates in the equilibrium relation also indicate the estimated long-run elasticities with respect to construction manpower, showing the presence of an elastic and positive link with construction output, and negative but inelastic relationship with labour productivity, interest rate and construction material price. The strong relationship between construction output and manpower demand reflects that shrinking of the output has a severe impact on the creation of long-term employment in the construction sector. Hence, introducing strong measures and effective strategy focusing on this aspect is critical to the development of the construction labour market.

The signs of coefficients in the cointegration equation are consistent with the expected signs with the exception of the real wage level. The result indicates that increases in the labour wages will generally bring about upsurge of the construction manpower demand, *ceteris paribus*. This could happen when shortages of labour resources arise in the market during industrial booms. It is also consistent with the findings by Crane and Nourzad (1998) in the manufacturing industry of Milwaukee. For a fuller explanation of wage determination and the existence of wage elasticity, the supply side of individual labour markets should be further examined. Williams (2004) also explains that when shortages of labour occur, firms try to attract suitable employees by offering wages higher than those similar employers offer elsewhere and *vice versa*.

7.3.3 Vector error-correction model and Granger causality tests

As a cointegrating relationship has been found among the variables, the cointegration series can be represented by a vector error correction model (VECM) according to the Granger representation theorem (Engle and Granger, 1987). In VECM, deviation of manpower demand from its long-run equilibrium path will, in the short term, feed on its future changes in order to force its movements towards the equilibrium state.

According to the VEC specification shown in Equation 5.7, the proposed VEC model for the manpower demand of the Hong Kong's construction industry can be written as:

$$\Delta d_t = \delta + \alpha(\beta' y_{t-1} + \rho_0) + \sum_{i=1}^{5} \gamma_{1,i} \Delta d_{t-i} + \sum_{i=1}^{5} \gamma_{2,i} \Delta q_{t-i} + \sum_{i=1}^{5} \gamma_{3,i} \Delta rw_{t-i}$$
$$+ \sum_{i=1}^{5} \gamma_{4,i} \Delta mp_{t-i} + \sum_{i=1}^{5} \gamma_{5,i} \Delta br_{t-i} + \sum_{i=1}^{5} \gamma_{6,i} \Delta lp_{t-i} + u_t \qquad (7.2)$$

where α is the adjustment coefficient, β represent the long-run parameters of the VEC function, the $\gamma_{j,i}$ reflects the short-run aspects of the relationship between the independent variables and the target variable.

Table 7.3 reports the error correction model's estimates for the aggregate manpower demand. Detailed outputs of the cointegration analysis and VECM are recorded in Appendix F. Further to the long-term relationships among the variables, the coefficients capturing the short-run dynamics are shown in the table, together with a test statistic for the significance of each estimated parameter. In the search for a more satisfactory specification, various additional regressors including the series measuring the capital stock and the level of capacity utilisation in construction were attempted to be incorporated but were finally discarded from the specification because there were not statistically significant at the 5% significance level. Equally, a number of proxy variables including time trends, for approximating technological change, were examined and discarded. Other factor price variables, such as exchange rates and consumer price indices were also considered but were not found to improve the specification as indicated in Table 7.3. The VECM specification shows that the construction manpower demand is significantly affected by construction output and labour productivity. In addition, the lagged manpower demand and the independent variables have a significant role to play to explain the demand.

Variables	Δd_t				
$\boldsymbol{\delta}$	0.0002	(0.0390)			
$\boldsymbol{\alpha}$	-0.2010	(1.3525)$^{\#}$			
$\boldsymbol{d_{t-1}}$	1				
$\boldsymbol{q_{t-1}}$	-1.2843	(-13.3587)$^{\#\#\#}$			
$\boldsymbol{rw_{t-1}}$	-0.8063	(-3.7474)$^{\#\#\#}$			
$\boldsymbol{mp_{t-1}}$	0.4137	(3.1939)$^{\#\#\#}$			
$\boldsymbol{br_{t-1}}$	0.0127	(1.5549)$^{\#}$			
$\boldsymbol{lp_{t-1}}$	0.7665	(8.1454)$^{\#\#\#}$			
$\boldsymbol{\rho_0}$	-0.6263				
	t-1	***t-2***	***t-3***	***t-4***	***t-5***
$\boldsymbol{\Delta d}$	0.4061	0.2879	0.2037	0.6016	0.4528
	(1.4435)$^{\#}$	(1.0082)$^{\#}$	(0.7996)	(2.3597)$^{\#\#}$	(1.9023)$^{\#\#}$
$\boldsymbol{\Delta q}$	-0.4286	-0.1232	-0.1321	-0.3863	-0.6033
	(-1.5530)$^{\#}$	(-0.3871)	(-0.4393)	(1.3242)$^{\#}$	(-2.4282)$^{\#\#\#}$
$\boldsymbol{\Delta rw}$	-0.0362	-0.1030	0.1616	0.0486	-0.0129
	(-0.2762)	(-0.8246)	(1.4360)$^{\#}$	(0.4158)	(-0.1326)
$\boldsymbol{\Delta mp}$	-0.2074	0.3795	0.5647	-0.5586	0.0441
	(-0.5682)	(1.0047)	(1.4210)$^{\#}$	(-1.4887)$^{\#}$	(0.1197)
$\boldsymbol{\Delta br}$	0.0138	-0.0090	0.0284	-0.0628	-0.0077
	(0.4918)	(-0.3468)	(1.1023)	(-2.2654)$^{\#\#}$	(-0.2563)
$\boldsymbol{\Delta lp}$	0.3661	0.0694	0.1309	0.4878	0.4496
	(1.9031)$^{\#\#}$	(0.3059)	(0.6103)	(2.2607)$^{\#\#}$	(2.3979)$^{\#\#}$
R-squared	0.4826		$^{\#\#\#}$ t-statistic significant at .01 level		
Sum sq. resids	0.0472		$^{\#\#}$ t-statistic significant at .05 level		
S.E. equation	0.0335		$^{\#}$ t-statistic significant at .1 level		
Log likelihood	167.2234				

Note: d, $\log_e$ of manpower demand; q, $\log_e$ of construction output; rw, $\log_e$ of real wage; br, $\log_e$ (1+ interest rate); lp, $\log_e$ of labour productivity; values in parenthesis are t-statistics

Table 7.3 Estimation results: vector error correction (VEC) model of the Hong Kong construction manpower demand

An important finding from the dynamic model is that the error correction term (α) is positive and statistically significant. The figure reflects that the previous deviation is adjusted quarterly towards the equilibrium by 20.1 percent between actual and expected construction manpower demand. This infers that the adjustment process in the labour market is somewhat precarious and sensitive. The respective adjustment coefficients reveal how the independent variables respond to the demand pressure in precisely the way anticipated for achieving long-term labour demand equilibrium. The importance of the error correction term demonstrates the amount of information relevant to near-term forecasting, that is embodied in the VECM modelling strategy's presumption that the short-run data generating process includes pressures to adjust toward long-run equilibrium. By multiplying the adjustment coefficient by the corresponding long-term parameters, the respective adjustment error term for each independent variable can be obtained.

In addition, the VEC specification was used to test the Granger causality of the explanatory variables. Table 7.4 shows the results of the Granger-causality tests. Applying Wald tests and joint *F*-tests, the null hypotheses that the independent variables do not Granger-cause the construction manpower demand can be rejected at the 1% significance level. In addition, the significance of the coefficient of α also suggests that the independent variables Granger-cause a deviation of the manpower demand from the long-run equilibrium in the previous quarter. Therefore, it is concluded that all the variables Granger-cause the construction manpower demand, implying that the past values of these variables are useful to forecast the demand in both short-run and long-run.

	Weak Granger-causality		Strong Granger-causality	
Null hypotheses	Chi-square	Probability	F-statistics	Probability
Construction output does not Granger-cause construction manpower demand	191.5704	0.0000	26.6632	0.0000
Real wage does not Granger-cause construction manpower demand	16.7972	0.0049	4.8200	0.0004
Material price does not Granger-cause construction manpower demand	19.5928	0.0019	6.3521	0.0000
Bank rate does not Granger-cause construction manpower demand	25.0814	0.0001	5.8560	0.0001
Labour Productivity does not Granger-cause construction manpower demand	209.0795	0.0000	47.2565	0.0000

Table 7.4 Results of Granger-causality tests based on the VEC model

7.3.4 Model verification

Various diagnostic tests on the residuals of the VEC model were applied to detect any significant departure from the standard assumptions. These included the Lagrange multiplier tests (LM) for up to respectively one and forth order serial correlation in the residuals, White's test (White, 1980) for heteroscedasticity (H) in the residuals and for model misspecification, the Jarque-Bera test for normality (NORM) of the residuals (Jarque and Bera, 1980). The results of the diagnostic tests reported in Table 7.5 indicate that the residuals from the estimated VEC model pass the tests at 95% significance levels, and hence, there is no significant departure from the standard assumptions. The model's predictive ability was also verified using Chow's second test. Further, the cumulative sum (CUSUM) test and cumulative sum of squares (CUSUMSQ) test were used to examine the parameter stability of the short-rum VECM model as suggested by Brown *et al*. (1975). The cumulative sum of the recursive residuals and squares falls within the 5% significance lines, indicating that the estimated coefficients are stable across the sample period. Therefore, there is no evidence of problems related to serial correlation, heteroscedasticity, non-normal errors, instable parameters, or predictive failure.

Diagnostics	**Statistics**	
LM(1)	1.4305	(0.2317)
LM(4)	2.7202	(0.6057)
H	73.9884	(0.4131)
NORM	0.3712	(0.8306)
CHOW	1.2587	(0.2554)

Note: LM(*p*) is the Lagrange multiplier test for residual serial correlation with *p* lag length; H is White's test for heteroscedasticity; NORM is Jarque-Bera test for normality of the residuals; CHOW is Chow's second test for predictive failure by splitting the data at 1st quarter 1999; and figures in parentheses denote probability values.

Table 7.5 Diagnostic tests of the estimated VEC model

The predictive adequacy of the VEC model was further evaluated by comparing the forecasts with the actual manpower demand over the *ex post* forecasting period, i.e. 2003Q1–2005Q3 as shown in Table 7.6. The forecasts were also compared with the projections produced by the Box-Jenkins (BJ) model[15] which served as a benchmark. The ARIMA $(0,1,0)(0,0,1)^4$ model was fitted to the differenced manpower demand series and the model parameters were estimated using maximum likelihood. The descriptions of the Box-Jenkins approach and the details of the modelling process are reported in Appendix G.

15 Box-Jenkins approach is one of the most widely used univariate forecasting techniques because of its structured modelling basis and acceptable forecasting performance (Maddala, 2001). However, the limited structure in this approach makes them reliable only in the short run (Wong *et al*., 2005b).

The mean absolute percentage error (MAPE) and Theil's *U* inequality coefficients were used to quantitatively measure how closely the forecasted variable tracks the actual data. The prediction percentage error of VEC model is consistently within the acceptable limit of 10%, giving a fairly low MAPE i.e. 4.52%. In contrast, the forecasting performance of the BJ model is comparatively inferior to that of VEC model, giving 12.96% of the MAPE. The Theil's *U* statistics also reveal that the developed VEC model has a high predictability. The validation further asserts that multivariate forecasting technique is more suitable than univariate technique for estimating the aggregate manpower demand.

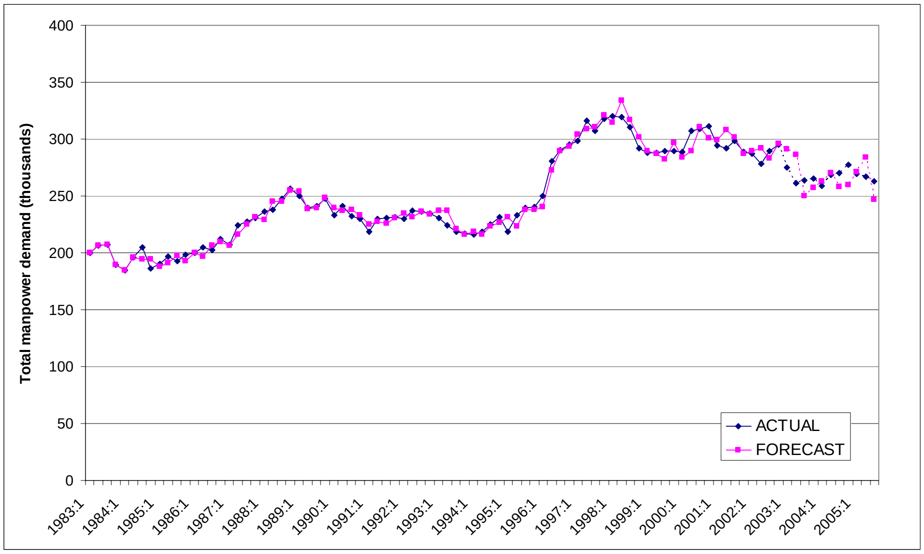
		VEC		**BJ**	
Period	Actual values	Forecast values	Percentage error	Forecasts values	Percentage error
2003Q1	275336	291395	5.83%	297628	8.10%
2003Q2	261687	286350	9.42%	295641	12.97%
2003Q3	263394	250125	-5.04%	299419	13.68%
2003Q4	265267	256938	-3.14%	303367	14.36%
2004Q1	258676	262768	1.58%	303367	17.28%
2004Q2	268622	269978	0.51%	303367	12.93%
2004Q3	270017	257829	-4.51%	303367	12.35%
2004Q4	277714	259546	-6.54%	303367	9.24%
2005Q1	269589	270820	0.46%	303367	12.53%
2005Q2	266619	284021	6.53%	303367	13.78%
2005Q3	263017	246906	-6.13%	303367	15.34%
		MAPE =	4.52%	MAPE =	12.96%
		U =	0.0263	*U* =	0.0615

Note: MAPE is mean average percentage error; *U* is Theil's *U* statistics.

Table 7.6 Evaluation of accuracy of the forecasts at aggregate level

Figure 7.2 shows graphically the demand estimation generated from the forecasting model and the actual manpower demand over the *ex post* simulation period and the *ex post* forecasting period i.e. 1983Q1–2002Q4 and 2003Q1–

2005Q3 respectively, indicating adequate goodness of fit of the developed VEC model. Hence, the results of the diagnostic tests and the evaluation of forecasts verify that the developed VEC model is adequately efficient and robust to forecast the short- to medium-term aggregate manpower demand for the construction industry of Hong Kong.



Note: solid line – *ex post* simulation period; dotted line – *ex post* forecasting period

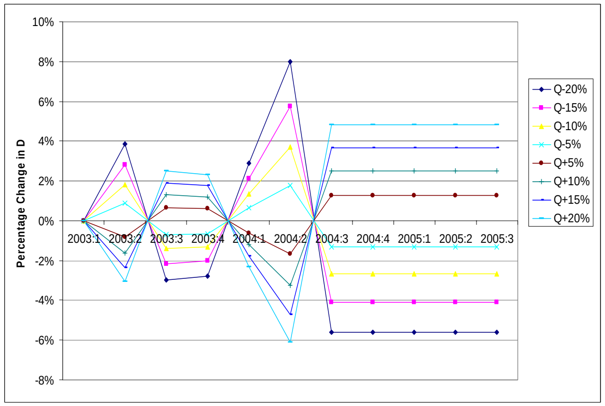
Figure 7.2 Predictability of the VEC model

7.3.5 Sensitivity analysis

The effects on the construction manpower demand are expected to be caused by the suggested demand specification. The accuracy of the manpower demand forecast therefore essentially relies on the estimations of independent variables. However, these estimations are also volatile in nature and can be simply estimated from the information available at the time of forecast. Thus it is necessary to examine how sensitive the prediction models will be, when key factors deviate from their estimates. The key factors' estimate errors are altered at ±5% intervals to examine the effects on the manpower demand prediction across the ex post forecasting period i.e. 2003Q1–2005Q3, using the developed VEC model as indicated in Table 7.3.

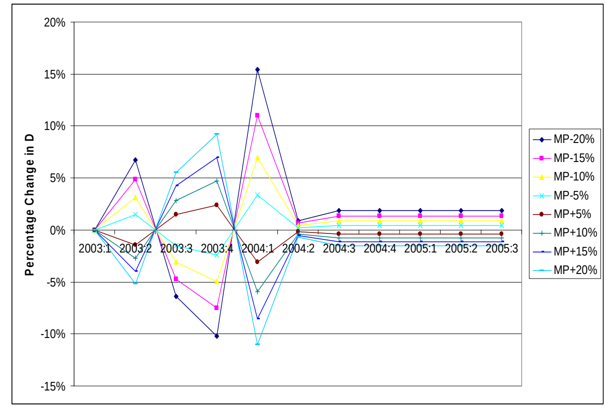
Figure 7.3 shows the results of the sensitivity analysis for the five key variables. It is interesting to find that the effects on the aggregate manpower demand, due to the deviations from the estimated key variables, vary enormously in the short-term. These reflect the dynamic feature of the VEC model. In contrast, the variations of the construction manpower demand, except the deviations raised by bank interest rate, remain constant after a six-quarter period. This shows the long-term equilibrium relationship between the key variables and the aggregate construction manpower demand.

Throughout the analysed period of the sensitivity analysis, the construction material price is the most sensitive construction demand factor in the short-run. The changes on manpower demand have a dramatic short-term effect ranges from -10.2% to 15.4% at ±20% variations of the material price estimates. The changes however are relatively small and stable in the long-run. In addition, the interest rate variations will have relatively volatile but minimal effect on the level of construction manpower demand.

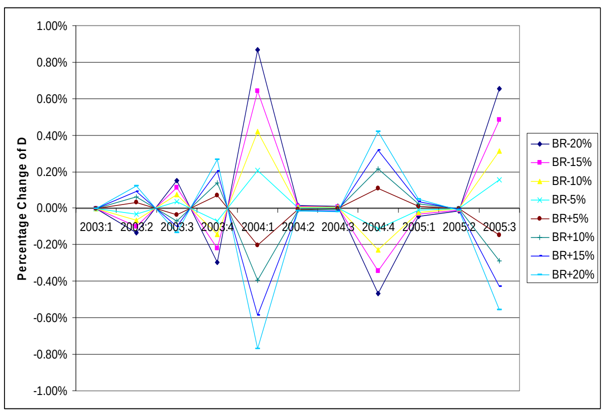


Construction Output

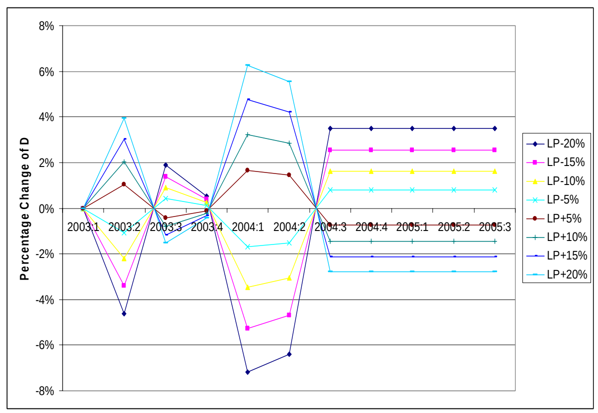
Real Wage



Material Price



Interest Rate



Labour Productivity

Figure 7.3 Sensitivity analysis of the VEC model

The results further indicate that the key factor affecting construction manpower demand is the impact of construction output. Faster growth in construction output benefits the amount of manpower required in the long-run. Increasing 5% of construction output can, on average, induces approximately 1.3% expansion of the total manpower demand. In addition, altering wage levels and labour productivity also significantly affects the construction manpower demand both in the short-run and long-run.

The findings of the sensitivity analysis also suggest that the developed VEC model is fairly 'linear' within certain limits. Thus these results can be interpolated or extrapolated *pro rata* to assess the effect of slightly larger or smaller changes. It should be noted that these results are peculiar to the aggregate manpower demand model being developed. They merely reflect the details of the specification of the model and its data base. Nevertheless, the information provided from the analysis provides a useful guide to the effect of changes in the key variables on construction manpower demand.

7.4 OCCUPATIONAL SHARE MODELS

The model for forecasting aggregate manpower demand for the Hong Kong construction industry, based on the Johansen cointegration procedure and error correction modelling technique has been developed in the previous section. Briscoe and Wilson (1993), however, stressed that if the model forecasts are to be of value for effective employment planning, disaggregated projections are required. Thus it is imperative to disaggregate the total projections into their skill components. The aim of this section is therefore to forecast the occupational share using time series modelling techniques. Two separate levels are involved in modelling the trend of occupational share: (i) broad occupations and (ii) detailed occupations.

7.4.1 Board occupational level

At the broad occupational level, seven occupations are included in the share analysis: (i) Managers and Administrators; (ii) Professionals; (iii) Associate Professionals; (iv) Craft and Related Workers; (v) Plant and Machine Operators and Assemblers; (vi) Clerks, and (vii) Elementary Occupations. The series of available data collected covers these seven occupations from the first quarter of 1993 to the third quarter of 2005, giving a total of 51 data points. Analogous to the aggregate model, the first 40 quarterly records were utilised for developing the model, while the remaining 11 data points were used to evaluate the predictions generated from the occupational share models.

Based on the previous specifications from the literature, the occupational share is affected by the construction output cycle, technology, capacity utilisation and various work-mix variables. The work-mix variables include all construction output series disaggregated by broad trade group, and by nature of construction activity issued by the Census and Statistics Department (see section 4.5.2). Multiple regression analysis was applied to model the occupational share at this level as shown in the Equation 5.8. The proposed broad occupational share estimate for the construction industry of Hong Kong thus can be represented by the following specification:

$$P_s = \alpha + \beta_1 TIME + \beta_{i2}\sum_{i=0}^{4} CEI_{t-i} + \beta_{i3}\sum_{i=0}^{4} q_{t-i} + \beta_{i4}\sum_{i=0}^{4} arch_{t-i} + \beta_{i5}\sum_{i=0}^{4} civ_{t-i} + \beta_{i6}\sum_{i=0}^{4} sf_{t-i} + \beta_{i7}\sum_{i=0}^{4} pi_{t-i}$$
$$+ \beta_{i8}\sum_{i=0}^{4} pub_{t-i} + \beta_{i9}\sum_{i=0}^{4} pri_{t-i} + \beta_{i10}\sum_{i=0}^{4} oth_{t-i} + \beta_{i11}\sum_{i=0}^{4} gen_{t-i} + \beta_{i12}\sum_{i=0}^{4} spe_{t-i} + \beta_{i13}\sum_{i=0}^{4} va_{t-i} \qquad (7.3)$$

where,

P_s	=	Percentage share for labour demand of occupation *s*
TIME	=	Time variable (1=1993Q1, 2=1993Q2…)
CEI	=	Capital to employment index
q	=	$\log_e$ of total construction output in HK$million
arch	=	$\log_e$ of construction output in erection of architectural superstructure
civ	=	$\log_e$ of construction output in civil engineering construction
sf	=	$\log_e$ of construction output in site formation & clearance
pi	=	$\log_e$ of construction output in piling & related foundation work
pub	=	$\log_e$ of construction output at the public sector
pri	=	$\log_e$ of construction output at the private sector
oth	=	$\log_e$ of construction output at locations other than sites for general trades and special trades
gen		$\log_e$ of construction output at locations other than sites for general trades (decoration, repair and maintenance)
spe		$\log_e$ of construction output at locations other than sites for special trades (carpentry, electrical and mechanical fitting, plumbing and gas work)
va	=	$\log_e$ of value added in construction

The regressors, except TIME and CEI, were transformed to natural logarithmic form as they displayed lognormal distributions. The capital to employment index and value added series were compiled from the reports of *Principal Statistics for All Building and Civil Engineering Establishments* issued by the C&SD. Table 7.7 reports the result of the model fitting process based on Equation 7.3 for the seven broad occupations over the sample period 1993Q1 to 2002Q4. Initially, all error terms except the model for 'professionals' and 'clerks' have autocorrelation problems as indicated by the Durbin-Watson statistics. An autoregressive error model with autoregressive parameter (v) was therefore applied to adjust the estimated serial correlation. The results from the corrected best-fit run of multiple regression analysis for each occupation show reasonably good R^2 values and significant F statistics. The detailed results of the share analysis are presented in Appendix H.

The output variable signs show no particular pattern as they are being used to explain occupational shares rather than absolute levels of industrial manpower demand. However, it is interesting to discover that the construction workload has a positive and significant effect on the share of the Craft and Related Workers, but that share decreases as time elapses, *ceteris paribus*. This explicates the decreasing trend of the demand for the crafted related workers in the local construction industry. In addition, the technology variable i.e. capital to employment index (CEI) is found to be significant in explaining the occupational shares in five out of the seven regression equations. This implies that the technological changes as well as the workload in different sectors have a critical impact on the share of individual broad occupational groups.

Regression Models			R^2	DW	NORM	CHOW
P_{ma}	=	$0.4003^{***} – 0.0663\ oth_{t-3}^{***} + 0.0401\ spe_{t-1}^{***} + 0.0226\ civ_{t-3}^{***} – 0.0284\ pub_{t-4}^{***} + v_t$	0.5626	2.0550	1.3128 (0.5187)	0.56 (0.8437)
v_t	=	$0.3661v_{t-1}^{**} – 0.3457v_{t-4}^{**} + \varepsilon_t$				
P_p	=	$– 0.1067^{*} + 0.0122\ civ_{t-3}^{***} – 0.9013\ CEI_{t-1}^{***} – 0.0106\ pub_t^{***} + 0.0141\ q_{t-2}^{*} + \varepsilon_t$	0.8250	2.0017	0.1054 (0.9487)	2.07 (0.0645)
P_{ap}	=	$0.3224^{***} – 4.4094\ CEI_t^{***} – 0.0200\ arch_{t-4}^{***} + v_t$	0.8945	1.9956	1.9141 (0.3840)	0.33 (0.9724)
v_t	=	$– 0.5082v_{t-2}^{***} – 0.3817v_{t-4}^{**} + \varepsilon_t$				
P_{cw}	=	$0.1660 + 0.0526\ q_t^{*} – 0.0038\ TIME^{**} + v_t$	0.8141	1.7740	1.5541 (0.4061)	1.66 (0.1403)
v_t	=	$0.8891v_{t-1}^{***} + (0.000297^{***} – 8.22 \times 10^{-24}\ \varepsilon_{t-1}^{2})^{1/2} e_t$				
e_t	~	$IN(0,1)$				
P_{po}	=	$0.0808 + 0.0122\ pub_{t-3}^{***} – 0.9343\ CEI_{t-2}^{***} – 0.0233\ arch_{t-1}^{***} + 0.00997\ pi_{t-4}^{***} + v_t$	0.6357	1.9298	0.1881 (0.9102)	1.89 (0.0933)
v_t	=	$0.2744v_{t-1}^{*} + \varepsilon_t$				
P_{ck}	=	$0.0497^{***} – 1.3641\ CEI_t^{***} + 0.8090\ CEI_{t-4}^{**} + \varepsilon_t$	0.4863	1.8365	1.5010 (0.4072)	0.90 (0.5514)
P_{eo}	=	$– 0.3104^{***} + 0.0688\ cu_{t-1}^{***} + 0.0178\ pi_{t-2}^{***} – 4.2955\ CEI_{t-4}^{***} + 3.0767\ CEI_{t-2}^{***} – 0.0352\ arch_{t-3}^{**} + v_t$	0.7796	2.1171	1.8342 (0.3699)	0.95 (0.5116)
v_t	=	$– 0.3948v_{t-1}^{**} – 0.4019v_{t-2}^{**} + \varepsilon_t$				

Note: *** t-statistic significant at .01 level, ** t-statistic significant at .05 level, * t-statistic significant at .1 level; P_i, percentage share for occupation *i*; ma, managers and administrators, p, professionals, ap, associate professionals, cw, craft and related workers, po, plant and machine operators and assemblers, ck, clerks, eo, elementary occupations; DW is Durbin-Watson statistic; NORM is Jarque-Bera test for normality of the residuals; CHOW is Chow's second test for predictive failure by splitting the data at 2nd quarter of 1999; and figures in parentheses denote probability values.

Table 7.7 Regression equations derived for the share of broad occupations

The results of the LM tests suggest the presence of heteroscedasticity of the error variance for the 'Craft and Related Workers' equation, which causes inefficient OLS estimations. The test for craft occupations is significant in the order 1, which indicates that a first order ARCH model is needed to model the heteroscedasticity. The 'AR(1)-ARCH(1)' short memory process model was therefore fitted for the craft series as shown in the equation. Besides, all tolerance values are smaller than 0.1, indicating no multi-collinearity problem is posed. The normality tests are also not significant for all error terms of the derived regression equations. This is consistent with the hypothesis that the residuals from the estimated models are normally distributed. The Chow's second test also verifies the models' predictability to be robust and valid. These results imply that the broad occupational share can be effectively explained by these regression equations which incorporate different combination of the construction output cycle, time trend, technology and work-mix variables.

The predictive adequacy of the developed forecasting models is further evaluated by comparing the *ex post* forecasts with the actual occupational share over the period from 2003Q1 to 2005Q3 as shown in Table 7.8. Mean absolute percentage error (MAPE) was used to quantitatively measure the predictability of the developed forecasting models. The prediction percentage error of the developed share models, except for the 'Managers and Administrators', are within the acceptable limit of 10%. The deviation of forecasts may be due to the unexpected drop of the share of 'managers and administrators' following the second quarter of 2004.

Figure 7.4 shows graphically the share estimations of the seven broad occupations generated from the forecasting models and the actual share over the sample period and the *ex post* forecasting period i.e. 1983Q1–2002Q4 and 2003Q1–2005Q3 respectively, indicating adequate goodness of fit of the developed models. Hence, the coefficient of determination (R^2), diagnostic checks and the evaluation of forecasts indicate that the forecasting models for predicting share of broad occupations have a satisfactory predictive performance.

Period	Managers and Administrators			Professionals			Associate Professionals			Craft and Related Workers		
	Actual share	Forecast share	% error	Actual share	Forecast share	% error	Actual share	Forecast share	% error	Actual share	Forecast share	% error
2003Q1	6.6312%	6.5382%	-1.40%	4.0443%	4.1973%	3.78%	11.6759%	11.4239%	-2.16%	55.1377%	55.7336%	1.08%
2003Q2	6.2104%	6.2102%	0.00%	4.3703%	3.9861%	-8.79%	11.1296%	10.8692%	-2.34%	57.2104%	56.6741%	-0.94%
2003Q3	5.7512%	6.4759%	12.60%	4.4181%	4.0969%	-7.27%	11.6314%	11.1369%	-4.25%	57.4477%	56.0864%	-2.37%
2003Q4	5.7862%	6.6285%	14.56%	4.5382%	4.1198%	-9.22%	9.9536%	11.2957%	13.48%	59.0414%	55.3167%	-6.31%
2004Q1	6.6317%	7.0116%	5.73%	4.1497%	4.2509%	2.44%	11.3371%	11.6194%	2.49%	57.8763%	54.8046%	-5.31%
2004Q2	4.1454%	4.8239%	16.37%	4.3695%	4.4642%	2.17%	12.4555%	12.2585%	-1.58%	56.7767%	56.5463%	-0.41%
2004Q3	4.3098%	5.1592%	19.71%	3.9552%	4.4704%	13.03%	12.1672%	12.6577%	4.03%	57.4468%	56.3753%	-1.87%
2004Q4	5.0211%	5.6903%	13.33%	4.0458%	4.4637%	10.33%	10.9228%	12.9097%	18.19%	58.6295%	56.2775%	-4.01%
2005Q1	5.9167%	6.3409%	7.17%	4.1677%	4.4826%	7.56%	11.0650%	13.0637%	18.06%	59.8767%	55.3846%	-7.50%
2005Q2	4.2894%	5.3059%	23.70%	4.5152%	4.7480%	5.16%	12.7758%	13.4619%	5.37%	57.7286%	55.8406%	-3.27%
2005Q3	5.0347%	5.9523%	18.22%	4.7100%	4.9728%	5.58%	12.9508%	13.1678%	1.68%	56.9212%	53.9649%	-5.19%
		MAPE =	12.07%		MAPE =	6.85%		MAPE =	6.69%		MAPE =	3.48%

Period	Plant and Machine Operators and Assemblers			Clerks			Elementary Occupations		
	Actual share	Forecast share	% error	Actual share	Forecast share	% error	Actual share	Forecast share	% error
2003Q1	3.9254%	3.8727%	-1.34%	5.5392%	4.8953%	-11.63%	13.0462%	13.3391%	2.24%
2003Q2	3.4800%	3.8316%	10.10%	5.1379%	4.9330%	-3.99%	12.4614%	13.4959%	8.30%
2003Q3	3.7235%	3.9164%	5.18%	4.9523%	4.8713%	-1.64%	12.0759%	13.4163%	11.10%
2003Q4	3.7349%	3.9373%	5.42%	4.4256%	4.7965%	8.38%	12.5201%	13.9056%	11.07%
2004Q1	3.7527%	4.2932%	14.40%	4.8098%	4.8722%	1.30%	11.4428%	13.1481%	14.90%
2004Q2	3.5765%	3.5693%	-0.20%	4.2956%	5.1372%	19.59%	14.3809%	13.2006%	-8.21%
2004Q3	3.5580%	3.4152%	-4.01%	4.8679%	5.2235%	7.30%	14.1951%	12.6987%	-10.54%
2004Q4	3.0990%	3.1677%	2.22%	5.1666%	5.3089%	2.75%	13.1152%	12.1822%	-7.11%
2005Q1	2.9697%	3.0758%	3.57%	4.8708%	5.2548%	7.88%	12.1333%	12.3975%	2.18%
2005Q2	2.8526%	2.9972%	5.07%	4.6397%	5.3394%	15.08%	13.6986%	12.3071%	-10.16%
2005Q3	3.0059%	3.4096%	13.43%	4.7345%	5.1722%	9.25%	13.5428%	13.3604%	-1.35%
		MAPE =	5.90%		MAPE =	8.07%		MAPE =	7.92%

Note: MAPE is mean average percentage error

Table 7.8 Evaluation of accuracy of the forecasts at broad occupational level (2003Q1-2005Q3)

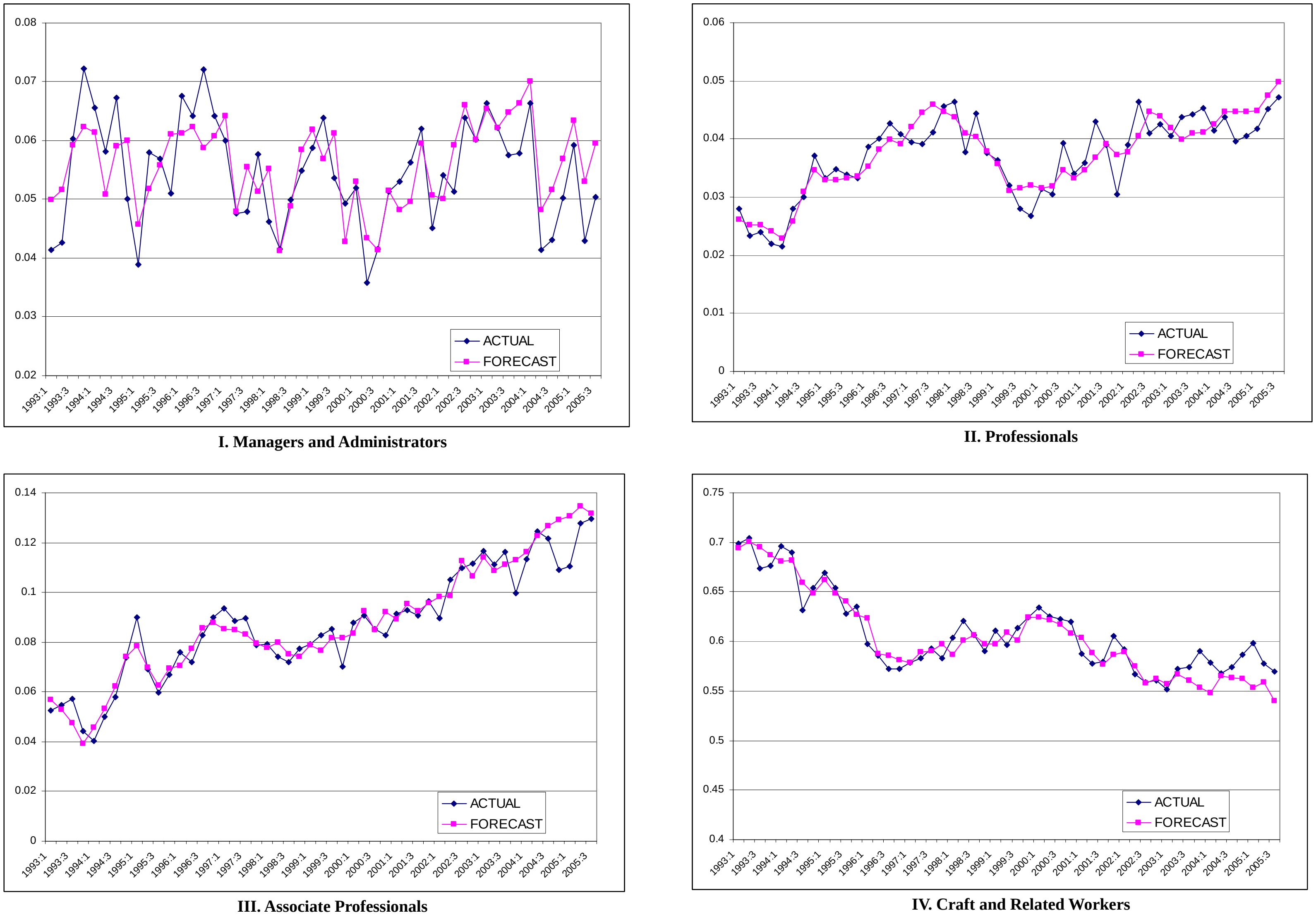
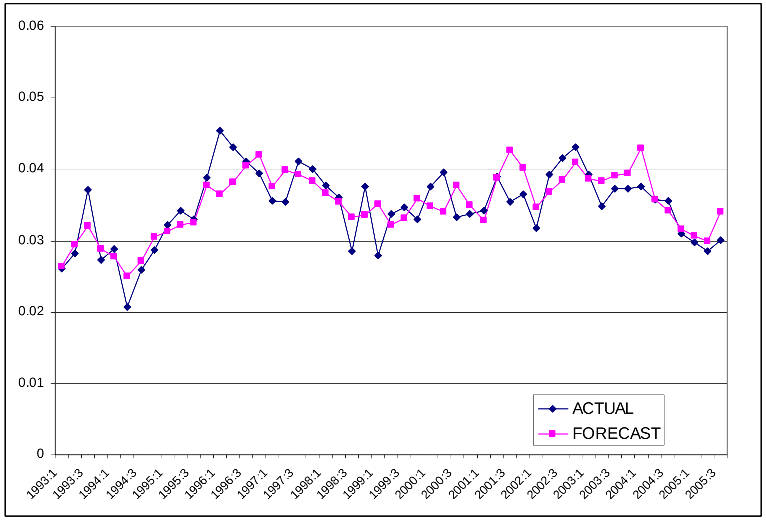
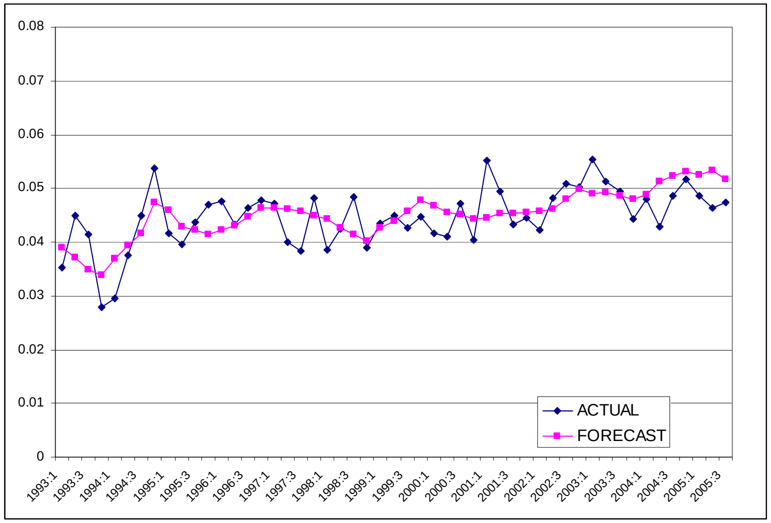


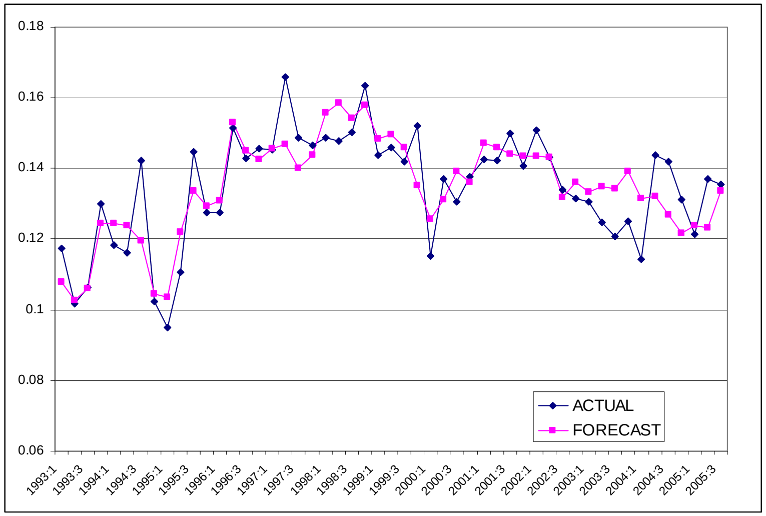
Figure 7.4 Predictability of the occupational share models



V. Plant and Machine Operators and Assemblers



VI. Clerks



VII. Elementary Occupations

Figure 7.4 Predictability of the occupational share models (cont'd)

7.4.2 Detailed occupational level

At the detailed occupational level, the occupational shares are estimated for 19 professional and 22 associate professional occupations. Out of these occupations, the occupational demand data for 11 professional and 13 associate professional occupations in the building and construction discipline were collected in the series of biennial VTC manpower survey reports, which are available from 1979 onwards, giving 13 data points. Exponential smoothing techniques were applied to estimate their occupational share. The data for the remaining occupations in the electrical and mechanical discipline is available from 2001 in a separate series of VTC survey report, giving only two data points. The moving average method was therefore used for estimating their share.

Table 7.9 shows the parameter estimations of the three exponential smoothing methods, covering 1979 to 2003, for each construction occupation. The best method for estimating the detailed occupation share is selected by comparing the root mean square error (RMSE). For example, the Holt-Winters method gives the smallest RMSE for the occupational share of Building Service Engineer, the estimates of the smoothing parameters turned out to be $\alpha = 0.0066$ and $\beta = 0.0001$ These results indicate the presence of a rather long memory of the past values, the zero value for beta in this case means that the trend component is estimated as nearly fixed and not changing. In addition, it is not surprising to find that some of the parameters are equal or close to one. This implies that the series is close to a random walk, where the most recent value is the best estimates of future values (QMS, 2000). The models developed at both broad and detailed occupation levels can be used to estimate the occupational share of the construction manpower demand.

Professional					Associate Professional				
Occupation	**Method**	**Constant** α	*B*	**RMSE**	**Occupation**	**Method**	**Constant** α	β	**RMSE**
Construction Manager/ Builder	SES	0.9990	-	0.0465	Assistant Safety Officer/ Safety Supervisor	SES	0.5700	-	0.0068
	DES	0.6120	-	0.0556		DES*	0.0010	-	0.0047
	HW*	0.9999	0.0001	0.0453		HW	0.0500	0.3501	0.0048
Civil Engineer	SES	0.9990	-	0.0628	Civil/ Structural/ Geotechnical Engineering Technician	SES	0.7780	-	0.0408
	DES	0.2860	-	0.0663		DES*	0.0090	-	0.0342
	HW*	0.9999	0.0001	0.0549		HW	0.5101	0.0500	0.0394
Construction Plant Engineer	SES	0.9220	-	0.0014	Clerk of Works/ Inspector of Works/ Works Supervisors	SES*	0.3000	-	0.0513
	DES	0.4340	-	0.0014		DES	0.2700	-	0.0536
	HW*	0.7900	0.1400	0.0014		HW	0.2400	0.9501	0.0558
Environmental Engineer	SES	0.9990	-	0.0134	Construction Plant Technician	SES	0.7380	-	0.0028
	DES	0.5900	-	0.0144		DES	0.3800	-	0.0026
	HW*	0.9999	0.1400	0.0133		HW*	0.3100	1.0000	0.0024
Geotechnical Engineer	SES	0.1460	-	0.0127	Construction Purchaser/ Storekeeper	SES*	0.9620	-	0.0084
	DES*	0.0010	-	0.0113		DES	0.3060	-	0.0091
	HW	0.5700	0.1000	0.0161		HW	0.9600	0.0000	0.0084
Safety Officer	SES	0.9990	-	0.0079	Estimator	SES*	0.1600	-	0.0279
	DES*	0.0010	-	0.0050		DES	0.2000	-	0.0292
	HW	0.6700	0.0000	0.0056		HW	0.1900	1.0000	0.0282
Structural Engineer	SES*	0.5660	-	0.0272	Interior Design Technician	SES	0.3880	-	0.0084
	DES	0.3180	-	0.0291		DES	0.1440	-	0.0082
	HW	0.5800	0.2200	0.0297		HW*	0.1800	1.0000	0.0081
Town Planner	SES*	0.0010	-	0.0090	Civil/ Structural/ Geotechnical Design Technician	SES*	0.0460	-	0.0366
	DES	0.4880	-	0.0098		DES	0.3040	-	0.0412
	HW	0.9600	0.0200	0.0091		HW	0.0600	0.0100	0.0372
Engineering Geologist	SES	0.9990	-	0.0021	Laboratory Technician (Construction Materials/ Soils)	SES*	0.0010	-	0.0098
	DES	0.5700	-	0.0022		DES	0.0010	-	0.0098
	HW*	0.9999	0.1500	0.0021		HW	0.0900	0.0000	0.0104
Quality Assurance Engineer	SES	0.9990	-	0.0062	Site Agent	SES	0.6320	-	0.0160
	DES	0.8100	-	0.0051		DES*	0.3720	-	0.0129
	HW*	0.9999	0.5500	0.0050		HW	0.6200	0.2400	0.0130
Building Services Engineer	SES	0.7880	-	0.0188	Site Foreman	SES	0.7280	-	0.0558
	DES	0.1520	-	0.0154		DES	0.4260	-	0.0411
	HW*	0.0066	0.0001	0.0136		HW*	0.2899	1.0000	0.0410
					Quality Assurance Engineer	SES	0.9990	-	0.0034
						DES	0.9990	-	0.0017
						HW*	1.0000	1.0000	0.0017
					Building Services Engineering/ Electrical Engineer/ Mechanical Engineer Technician	SES	0.9340	-	0.0268
						DES	0.4760	-	0.0231
						HW*	0.9500	0.0000	0.0222

Note: * indicates best fit model

Table 7.9 Comparison of the non-seasonal exponential smoothing models

7.5 DISCUSSION OF THE RESULTS

7.5.1 Applications of the models

The forecasting models developed at the aggregate level, broad occupational level and detailed occupational level were validated and can be used concurrently to generate reliable forecasts of the short- to medium-term construction manpower demand. The manpower demand forecasts are valuable to aid the policy makers and training planners to predict labour resource requirements and thus formulate training strategies. These demand-side forecasts, together with the future labour force supply, allow the construction industry to identify early imbalance in the occupations of the labour market.

This study reveals that the long-run aggregate construction manpower in Hong Kong is determined by combining the driving force from the five independent variables in the estimated model. The model precedes those relatively primitive employment specifications carried out in a bivariate setting (e.g. Pehkonen, 1991; Harvey *et al*., 1986). The findings assert that the construction output cycle and labour productivity are the most significant factors driving the labour demand in the construction industry. Addressing these two factors on policy formulation and implementation is critical in order to maintain a sustainable labour market. However, these results indicate the potential importance of other price factor terms such as bank interest rate, wages and construction material price in explaining labour demand. This empirical relationship derived is also useful for industrial policy formulation and simulation.

As an illustration of forecasting, Table 7.10 and Table 7.11 report sets of yearly *ex ante* occupational demand forecasts from 2006 to 2008, based on the developed VEC model and the estimations of the occupational share models. A constraint is applied to ensure that all the occupational shares sum to unity. The forecasting models were re-estimated to project the manpower demand by incorporating the latest data points i.e. 2005Q3 (see Appendix I for the details of the revised models). The estimates of the independent variables are required to yield the aggregate manpower demand and the share at the broad occupational level. The initial forecast values for these variables are based on log linear trend extrapolation as shown in Equation 7.4 (see Appendix J).

$$Y = \beta_0 + \beta_1 TIME + \mu; \qquad (7.4)$$

where Y represents $\log_e$ of independent variables, *TIME* is a time trend variable (1=1983Q1, 2=1983Q2…); the parameters β_1 is the regression coefficient for the time variable; the intercept β_0 is the regression constant; and μ is the error term.

Aggregate manpower demand for the construction industry is projected to recover slowly from the recession in 2003/4 because of the anticipated stable construction workload in the forecasting period. Forecasts for broad occupations depend not only upon the level of industry output but also upon the composition of the type of workload in the industry. The results indicate a continuation of long-term trend growth for non-manual occupations such as professionals and associate professionals. In contrast, the decline of the share of crafted and related workers is anticipated to continue.

Occupations	2006	2007	2008
Managers and administrators	12761	14742	15119
Professionals	11090	11624	12132
Associate professionals	33807	36037	37863
Craft and related workers	148851	147117	147749
Plant and machine operators and assemblers	10769	10852	10989
Clerks	11140	11924	12236
Elementary occupations	32496	33277	34327
Total	260914	265573	270315

Note: occupational shares are constrained to sum to 100 percent

Table 7.10 Occupational share forecasts for broad occupations (2006–2008)

Professional				Associate Professional			
Occupations	**2006**	**2007**	**2008**	**Occupations**	**2006**	**2007**	**2008**
Construction Managers/ Builders	1360	1494	1617	Assistant Safety Officers/ Safety Supervisors	860	936	1003
Civil Engineers	3166	3039	2961	Civil/ Structural/ Geotechnical Engineering Technicians	5881	6463	6979
Construction Plant Engineers	77	86	94	Clerk of Works/ Inspector of Works/ Works Supervisors	8327	8509	8585
Environmental Engineers	772	854	930	Construction Plant Technicians	502	593	680
Geotechnical Engineers	532	533	527	Construction Purchasers/ Storekeepers	491	502	507
Safety Officers	816	908	994	Estimators	1035	1058	1067
Structural Engineers	1437	1492	1530	Interior Design Technicians	957	1129	1291
Town Planners	438	455	467	Site Agents	1297	1255	1194
Engineering Geologists	139	156	173	Laboratory Technicians (Construction Materials/ Soils)	925	945	954
Quality Control/ Assurance Engineers	667	788	906	Civil/ Structural/ Geotechnical Design Technicians	524	536	540
Building Services Engineers	1535	1660	1771	Site Foremen	8174	8622	8971
Control and Instrumentation Engineers	6	7	7	Quality Control/ Assurance Technicians	1177	1413	1639
Electrical Engineers	48	50	51	Lift Technicians	121	124	125
Electronics Engineers	5	5	5	Draughtsman	20	20	20
Lift Engineers	15	16	16	Electrical Instrument and Meter Technicians	17	18	18
Mechanical Engineers	10	10	11	Electronics Technicians	27	28	28
Refrigeration/ Air-conditioning/ Ventilation Engineers	30	31	32	Building Services /Electrical /Mechanical Engineer Technicians	3121	3528	3901
Fire Services Engineers	24	25	25	Telecommunication Technicians	19	20	20
Engineering Managers	14	14	15	Refrigeration/ Air-conditioning/ Ventilation Technicians	129	132	133
				Supervisors	95	98	98
				Fire Services Technicians	104	106	107
				AV/ TV Service Technicians	3	3	3
Total	11090	11624	12132	**Total**	33807	36037	37863

Note: All occupational shares are constrained to sum to 100 percent

Table 7.11 Occupational forecasts for specific occupations (2006–2008)

Although these forecasts should not be interpreted as a precise outlook for construction manpower demand, they do provide an indication of the future manpower requirements and possible labour market structure based on the forecasts made by the developed forecasting models. The accuracy of the results obtained is undoubtedly sensitive to assumptions adopted, as well as to the underlying values of the independent variables of the developed econometric equations. The forecasts are therefore intended primarily to present the nature of a typical set of projections based on the mechanical forecasting models developed, rather than as a prediction of what is the likely manpower demand. However, if used in conjunction with more detailed local knowledge, the models can provide a useful benchmark for simulation analysis. The results of the sensitivity analysis can be built into a forecasting model for the construction industry to show the sensitivity of the manpower demand projections to alternative macroeconomic scenarios. Where the changes affect the demand, these results will mimic the effects of using the proposed forecasting models. The finding can provide a useful indication of the variation range possible.

7.5.2 Limitations of the models

i) The proposed models have been developed by making the best use of available data and forecasting approach. However, lack of comprehensive and frequent time series data at the detailed occupation level have caused the forecasts to be not comprehensive. If a similar approach to modelling the manpower demand for all specific skills in the construction sector, more comprehensive sets of time series employment data are required. In addition, and primarily owing to the constraint of data availability, relatively simple and non-structural forecasting methods i.e. exponential smoothing/moving average technique were adopted at the detailed occupational level. Hence, more robust and reliable forecasting technique should be applied at this level once frequent and reliable data are available.

ii) The forecasting models developed have merely involved the endogenous variables affecting the aggregate manpower and the occupational share within the construction industry. Further investigations and references are needed to examine the relationship between these variables in the models and the exogenous variables such as the Gross Domestic Product and price indices, in order to establish a more comprehensive forecasting framework.

iii) The developed manpower demand models are constrained to the local construction labour market. Undoubtedly neighbouring cities in the Mainland China and Macau increasingly require local construction personnel. It may not be sufficient to envisage the planning of construction skills in a purely domestic context. However, enormous international manpower data are needed to extend the current forecasting system.

iv) The industry-based forecasting model has similar constraint of the project-based model, every observation in the data set inevitably has made a certain contribution to the fit of the final model equations. As a result, any inaccurate records could have resulted in a distortion in the model and its predictive performance. Hence, the forecasting models should be regularly revised and updated by incorporating the latest data available.

v) As mentioned in Chapter Three, the reliability of the top-down forecasting method depends essentially on the accuracy of the arbitrary projections of the macroeconomic independent variables to predict manpower demand. However, as the sensitivity analysis previously indicated, the model is capable of producing a range of different forecasts dependent upon the values chosen for the key inputs and certain selected supposition.

vi) Time and limited resources have also inevitably constrained the forecasting process and precision of the forecasts. Although the forecasting techniques adopted in the study have proved to be a reasonably appropriate approach to predict the construction manpower demand in Hong Kong, qualitative information such as employers' views and expert knowledge can complement and adjust, if necessary, to the pure quantitative estimates. A further limitation is that manual efforts are still required to update the model and generate new sets of forecasts from the developed models. Hence, with the pace and availability of advanced computerised packages, adopting computerised forecasting system could undoubtedly further facilitate the manpower forecasting practice for the construction industry.

7.6 SUMMARY

The industry-based forecasting models for estimating construction manpower demand in Hong Kong have been developed. The models consist of three consecutive levels: (i) aggregate level; (ii) broad occupational level; and (iii) detailed occupational level. By applying Johansen's multivariate cointegration analysis, it was found that the aggregate manpower demand and the associated economic factors, i.e. construction output, real wages, material prices, bank rate and labour productivity are cointegrated. This indicates that these factors have a long-run equilibrium effect to determine the local construction manpower demand. Subsequently, a dynamic specification of the manpower demand for forecasting purposes equipped with vector error correction component has been developed. The model contains a long-run cointegrative relation and short-run dynamics among the identified variables. The error correction term was found to be statistically significant, implying that the adjustment process in the local labour market is sensitive.

The proposed forecasting model at the aggregate level was verified against various diagnostic statistical criteria and actual manpower demand figures. These tests indicate that the proposed model has a reasonably good predictive performance. In addition, sensitivity analysis was conducted to indicate the sensitivity of the construction manpower demand to the changes in a series of key indicators. The findings presented provide insights into the effects of these variables on the aggregate construction manpower demand.

Subsequent to the completion of the forecasting model for the aggregate construction manpower demand, forecasting models have been established to estimate the share for specific occupations. At the broad occupational level, a separate set of regression equations were formulated which make the respective occupational shares a function of trend, output cycle, technology, utilisation capacity and various work-mix variables. The regression equations were also validated against rigorous diagnostic tests and comparing with actual occupational shares. Lastly, exponential smoothing/smoothing average techniques were used to forecast the shares of specific professional and associate professional occupations. A set of *ex ante* manpower demand forecasts for 2006-2008 was derived as forecasting illustrations of the developed models.

The occupational share models, in association with the aggregated model, serve as a practical and robust tool to provide solid and reliable manpower demand estimates to help anticipate and respond swiftly to changing requirements in the construction sector in short-to medium-term (i.e. one to three years). The information provided by such assessments is a key input into decisions to be made about the scale and content of immediate actions to adjust different education and training programs. Government agencies, education providers companies and trade unions can also formulate corresponding strategies based on the manpower demand forecasts. These forecasts can benefit the industry to facilitate manpower planning and ultimately produce a well-planned and stable supply of well-trained workforce.

CHAPTER 8 CONCLUSIONS, CONTRIBUTIONS AND FURTHER RESEARCH

CHAPTER 8 CONCLUSIONS, CONTRIBUTIONS AND FURTHER RESEARCH

8.1 INTRODUCTION

This study was motivated by the need for an in-depth empirical analysis to forecast the manpower demand for the local construction industry in assisting human resource planning and policy formulation. The overall aim of this research was to develop manpower demand forecasting models, at both project level and industry level, for the construction industry of Hong Kong. Such models would benefit the industry by serving as a reliable aid to an active policy in the areas of manpower planning, training, and job creation.

To establish a manpower demand forecasting model framework at project and industry levels, the construction industry should understand the requirements for manpower forecasting system in construction, and make use of reliable methods for forecasting occupational demand. An awareness of these aspects is reflected in the research objectives of this study which are to: (i) review and evaluate existing manpower demand forecasting methods; (ii) determine the key requirements for manpower forecasting in the construction industry; (iii) identify determinants of both project-based and industry-based manpower requirements;

(iv) construct robust models to predict manpower requirements at project level and at industry level; and (v) test the reliability and sensitivity of the development models. Conclusions from these research objectives are presented in this chapter. The contributions to knowledge and the applications of the research are also highlighted. Lastly, recommendations are suggested to direct further research.

8.2 FINDINGS AND CONCLUSIONS

8.2.1 The need for advanced manpower demand forecasting models

The Hong Kong construction industry is recognised as being made an important contribution to the spectacular economic growth of the Territory (Chiang *et al*., 2004; CIRC, 2001). The industry has enjoyed a boom in the 1990s but was severely hit by the recent economic downturn. This contrast in circumstances has resulted in mismatches between labour demand and supply, subsequently has caused adverse effects on the development of the industry. The pace of technological development and the changing economic conditions, together with this imbalance in the labour market make necessary a more efficient and advanced tool for forecasting construction manpower requirements.

The contemporary manpower demand estimating methods developed in recent years, ranging from macroeconomic projections to surveys among enterprises have been reviewed. This review provides the base for further development of manpower forecasting models in this study. In particular, local forecasting models for prediction of construction manpower demand at both industry and project levels were examined. The forecasting models for the Hong Kong construction industry have been evaluated based on the identified forecasting requirements and an empirical analysis. The predictability of these local manpower forecasting models was found to be unsatisfactory, as indicated by considerable forecasting error. Hence, it was concluded that in-depth investigations were needed for developing advanced models to provide more reliable manpower forecasts.

At the project level, quantitative causal techniques have been extensively applied in modelling labour demand. Among the existing forecasting approaches, most forecasting models merely make use of the relationship between manpower demand and project size to estimate the project-based skill demand (e.g. the multiplier approach). More robust model is needed to facilitate effective manpower planning at project level by incorporating additional relevant variables into the existing univarable approach. At the industry level, the ‘top-down’ approach is considered to be the most suitable forecasting approach because of its ability to capture the determinants of the manpower requirements and dynamics in the labour market. It also allows the testing of “what if” scenarios, such as assessing the impacts of inter-sectoral output. The univariate projection method adopted locally has proved to be not adequate to provide reliable forecasts of construction manpower demand. Advanced econometric time series modelling is therefore recommended to derive the causal relationship between construction employment and economic environment.

8.2.2 Development of project-based manpower demand forecasting models

Due to the limitation of data availability, forecasting manpower demand at the project level is confined to site operatives. A review of the relevant literature and pilot study sought a set of key factors considered to affect project labour demand. These factors included project size, project type, construction method, project complexity, degree of mechanisation, management attributes, and expenditure on electrical and mechanical services. Labour records and project information from a total of 54 construction projects were then used to develop forecasting models for predicting the project-based labour demand by applying multiple linear regression (MLR) analysis.

In addition to establishing the model for estimating the total labour demand for a construction project, regression models were also developed for ten skilled trades: Bar Bender and Fixer; Carpenter (Formwork); Concreter; Electrician/Electrical Fitter; Excavator; Labourer; Metal worker/General Welder; Plant and Equipment Operator (Earthmoving Machinery); Plasterer; and Truck Driver. 50 out of the 54 sample projects formed the modelling data set, while the remaining four projects were the results of a random selection to verify the forecasting performance of the models. The results of the diagnostic tests and the assessment of forecasting performance enabled confirmation that the forecasting models developed in this study could provide reliable forecasts on the demand for construction personnel at the project level.

The derived forecasting models could be used for predicting construction project labour requirements as a function of labour demand determinants. The Government would also be able to make use of the regression equations to assess the number of jobs created by public investment. The results reveal that total labour demand for a construction project is related to the project characteristics including construction cost, project complexity, physical site condition, and project type. By specific skill trade, project cost is the most significant in the estimation of occupational labour requirements. Nevertheless, the demand for individual labour trades is also significantly determined by project type, project complexity attributes, and expenditures on E&M and mechanisation.

Even in areas with a generally abundant supply of labour, there may be times when some skilled labour is not available. The project-based manpower demand forecasting models make use of the labour deployment records and information of project particulars to estimate the labour demand. These labour estimates help formulate and implement necessary strategies in time to achieve different objectives. One objective is to provide the necessary built infrastructure to enable economic growth. It is imperative to estimate the labour requirements to ensure sufficient labour supply to complete the works at budgeted costs. Another objective is to use the construction industry as an economic regulator (Hillebrant, 2000). The Hong Kong Government has done just that in recent years to revive its recessionary economy through offering especially labour intensive contracts such as maintenance and small works. The amount and type of labour that a construction project needs, and the number of job opportunities created could be estimated by the project-based models.

8.2.3 Development of industry-based manpower demand forecasting models

The 'top-down' approach was selected in this study to build the industry-based occupational demand forecasting models. The forecasting framework consists of three separate levels: (i) aggregate level; (ii) broad occupational level; and (iii) detailed occupational level. Applying Johansen's methodology for multivariate cointegration analysis, it was found that the aggregate manpower demand and the associated economic factors i.e. construction output, real wages, material prices, bank rate and labour productivity were cointegrated in the long-run. A dynamic forecasting model was then developed using the vector error correction modelling (VECM) technique to estimate the aggregate manpower demand.

The derived forecasting model at the aggregate level was verified against various diagnostic statistical criteria. The medium-term forecasts generated from the VEC model were further compared with actual manpower demand figures. The results of the verification reveal that the forecasting model at the aggregate level has a reasonably good predictive performance. The error correction term was found to be statistically significant, implying that the adjustment process in the local construction labour market is sensitive. Additionally, sensitivity analysis was conducted to detect the sensitivity of the construction manpower demand to the changes in a series of key indicators using the VEC model.

Subsequently to the aggregate model, the occupational share models were established using time series analysis techniques. The forecasting model for estimating the shares of seven broad occupations was formulated from a set of regression equations which make the respective occupational shares a function of trend, output cycle, technology and various work-mix variables. Lastly, the shares of specific occupations were estimated using the exponential smoothing technique. The detailed occupational analysis was confined to the professional and the associate professional occupations because of the data availability problem. Various diagnostic tests were undertaken to validate the reliability and robustness of the developed occupational share models.

The methods applied and the results presented in this research provide insights into the effects of these variables on manpower demand. The construction output and labour productivity were found to be the most important and significant factors determining the quantity demand of construction manpower. Addressing these two attributes on policy formulation and implementation is critical to achieve a sustainable labour market. In addition, the demand for manpower was projected in the industry-based model for 2006-2008. Aggregate manpower demand for the construction industry is predicted to recover steadily. At the occupational level, a continuation of growth for professionals and associate professionals is anticipated whereas the share of crafted and related workers is anticipated to decline in the next three years. This prospect may prompt education institutions in construction to adjust their training strategies and enrollment quota.

The forecasting models derived in their present form can be served as a practical and robust tool to estimate the manpower required for the construction industry of Hong Kong for short- to medium-term (i.e. one to three years). The labour demand estimation can provide solid information to facilitate manpower planning. It enables policymakers to foresee the trend of manpower demand and formulate policies and training programmes tailored to deal effectively with the industry's labour resource requirements in the construction sector.

8.3 VALUE OF THE RESEARCH

This research study has initiated a comprehensive investigation of forecasting manpower demand for the Hong Kong construction industry. It presents the current application of manpower demand forecasting in both local and overseas contexts. It also provides a comprehensive review of previous studies on key determinants of manpower demand at project level and industry level. In addition, a pilot study was conducted to verify the determinants identified from the literature and explore the users' requirements for manpower forecasting in construction. These requirements are useful for developing the framework of manpower forecasting and can serve as a benchmark for future research to study and evaluate the capability of a manpower forecasting model. Forecasting models at respective levels have been subsequently developed based on the most appropriate estimating methodology, determinants of manpower demand and users' requirements. The findings from the research are influential to knowledge development in manpower forecasting and applicable to manpower planning in construction.

8.3.1 Contributions to knowledge

This research has made a considerable contribution to filling and updating the knowledge gap in the field of manpower forecasting, an area currently under-explored. The contemporary manpower planning practices, requirements of manpower forecasts for construction, manpower demand forecasting methodologies, and the key determinants of construction manpower demand have been explored from a comprehensive literature review. In particular, the review and the comparative evaluations of the different types of forecasting methodologies are of value to academics, policy-makers of government, public employment services and employment agencies, employers' organisations, unions and education institutions (Wong *et al*., 2004).

More importantly, this research provides a valuable theoretical frontier and offers a new attempt to improve in several ways the project-based and industry-based forecasts of manpower demand. At the project level, this study provides a series of algorithms and models for predicting construction project labour requirements as functions of labour demand determinants. The results indicate that occupational demand for a construction project depends not only on a single factor as applied in previous prediction models, but on a cluster of variables related to the project characteristics. At the industry level, this research provides an original application of advanced econometrics modelling techniques i.e. the cointegration analysis and vector error correction model, to estimate the future aggregate construction manpower demand. The factors affecting occupational demand and their lag relationships were also incorporated effectively in the regression equations at the broad occupational level. These offer an integrated and enhanced forecasting system for the construction industry of Hong Kong.

In addition, there are limited research studies on forecasting construction manpower especially in Asian countries. Most of the previous studies were based on practices in developed countries including the United Kingdom, the United States, the Netherlands and Germany. Although all labour markets deal with the hiring of labour services, different markets may have distinct characteristics due to the scale and speed of development, macro-economic conditions, and the political and social environment. Hence, the research findings and the methodology adopted in this study are particularly useful as a reference for a variety of industrial sector and cities in Mainland China and other Asian countries. By extending the study in worldwide collaboration with fellow researchers, our understanding of improving the vocational training system and developing a sustainable labour market can be further enhanced. Academic programmes in project management and construction economics can also be enriched and students can be trained in the areas of human resource planning and statistical forecasting.

8.3.2 Applications of the research

Understanding market processes is a key task of economic analysis (Smith, 2002). Manpower forecasts are made because they provide decision makers with a means of addressing important questions relating to education, training and choice of occupation (Hughes, 1991). As skill requirements in construction have noticeably been changing, a significant merit of this research outcome is the provision of a sound mechanism for predicting construction occupational demand so that immediate action and long-term strategies can be launched by corresponding organisations and training institutions, with the intention of meeting future training needs for the community.

At the project level, the forecasting models developed in this research serve as a convenient and practical tool for consultants and contractors to estimate the likely labour required for a given type of project. The labour demand estimation can provide solid information at the initial stage for human resource planning as well as labour cost budgeting. It also enables the Government to better estimate the number of jobs created arising from a new construction project. This can assist the Government to better plan the allocation of limited resources, especially at times of economic downturn, to maximise the job creation function through public expenditure. In addition, the model serves as a benchmark for future research to study the determinants of labour demand and forecasting labour demand for the construction industry.

Identifying and forecasting future skill requirements at sectoral level and implementing these requirements in the training system have long been the subject of intensive research effort and academic discussion. The industry-based models developed in this study offer thorough employment projections system that produce detailed intermediate-term occupational demand projections for the local construction industry. The forecasts provided by such assessments is a key input for adjusting education and training programs and strategies by government agencies, education providers companies and trade unions.

An early identification of the labour market nature and structure can help training systems lessen future skills mismatches in construction. However, the primary goal of the research is not to predict future developments to a very high degree of precision. Rather, the aim is to detect, by using present and past information on the labour market and making assumptions about dominant economic trends, the occurrence of major labour market trends occurring on the labour market in terms of construction employment by occupations needed in the future. Such information through policy formulation and implementation can help facilitate the development of industry designed to maintain relative balance for the various occupations in the labour market.

Although this research focuses on developing models for the Hong Kong construction labour market, a similar methodology can be replicated to develop models for more complex and diverse labour markets. The forecasts can be disaggregated by region and occupation in such markets, subject to the properties of the data series in terms of sample size, coverage, continuity, availability and speed of publication.

8.4 LIMITATIONS OF THE RESEARCH

This study has three major limitations. They are discussed as follows:

i) The research was confined to the Hong Kong construction industry at project level and industry level. Due to limited resources, the manpower forecasting at national level has not been covered. The impact of construction activities in neighbouring cities/countries such as mainland China and Macau has therefore not been incorporated. Forecasting manpower demand for construction companies is also excluded primarily because of the project-based nature of the industry.

ii) This research focuses on the demand-side of the labour market. In order to identify any imbalance and number of job openings of the future labour market, the future supply of manpower should also be further investigated and projected.

iii) The manpower demand forecasting in the study is a mechanical process. As noted, qualitative information such as employers' perception and expert knowledge and the findings extracted from the labour market analysis can be complementary to pure quantitative demand forecasts, especially for the new qualifications and skill requirements.

Despite these limitations, reasonably accurate and robust demand side models have been developed, sufficient for most practical forecasting purposes at the project and industry levels.

8.5 RECOMMENDATIONS FOR FURTHER RESEARCH

8.5.1 Refining the model specifications

The manpower demand forecasting models developed in this research have been verified and proved to be reliable. However, as noted in the previous section, time and limited resources have constrained the level of sophistication possible in certain aspects of the specification. The reported equations represent a first attempt to build a complete manpower demand forecasting model for the construction industry, using a set of well-known techniques and methodologies. Although the project-based model and the industry-based models at aggregate level and broad occupational level are based on a sophisticated econometric approach, there is still room to carry out further work with a view to improving the specifications.

In particular, the project-based demand forecasting model could be enhanced to derive superior equations by introducing a larger sample size with a wider range of project types and perhaps using non-linear modelling techniques. In addition, the occupational share equations for estimating the demand for detailed occupations at the industry level are relatively simple specifications, without dynamic characteristics and considering the relationship with determinants of the occupational share. Such modifications, however, will only be possible when more reliable and detailed data exists.

Improving the manpower statistics is therefore important for comprehensive manpower planning in construction. The existence of considerable discrepancies of the figures at the broad occupational level has been described in Chapter Four. This might greatly impede the accuracy of the forecasts of the detailed occupations. It is therefore highly recommended for the *General Household Survey* to develop a detailed occupational data series in future, in order to fill the present data gap, even though additional surveys may need to be initiated. It is also very important that the most recent statistics are incorporated into the data sets, as these values will be more relevant than data from earlier decades. There is an on-going need to re-estimate and check the equations of the models at regular intervals, preferably annually or biannually in order to overcome the time-lag problem and to be able to assess the impact of short-term developments (Neugart and Schömann, 2002). Such a process of checking may lead to new specifications of particular parts of the models.

In addition, extensive experimentation with the macro-factors is needed to assess the impact of the key external variables on the construction manpower demand forecast. The projection of total construction manpower demand is the central component of the industry-based model, because this forecast governs the occupational estimates. In Chapter Seven, the aggregate forecasting equation has been developed by incorporating five main explanatory variables in construction, namely, industrial output, real wages, material price, interest rates, and labour productivity. The values of each of these variables are in turn dependent upon changes in exogenous factors in the macroeconomy. However, both the global economy and Hong Kong government policy are subject to continuous change, thus it is difficult to anticipate far in advance the likely value of these macro determinants. The link between the macroeconomic forecasts and the industry-based model should therefore be further studied in order to obtain more realistic demand forecasts.

User feedback should be obtained as the models are put to use and the forecasts are distributed to those involved in manpower planning. One important group of users who might be expected to provide feedback information is government officers. They have a prime responsibility for estimating project-based and industry-based manpower demand and training provision but research resources are usually lacking to make longer-term predictions. Similar considerations apply to the various specialist trade associations and employer groups in the construction sector. If all these potential users are to benefit from the workings of the model, as envisaged in section 2.2, it is important that their feedback is taken into account in developing improved models.

8.5.2 Extending the forecasting models

The industry-based model has been developed for the Hong Kong construction industry, but as discussed in section 4.5, the definition of ‘construction’ is rather arbitrary in the final analysis. Inevitably, construction overlaps at a number of points with various engineering industries, materials supply, transport and communication and also with local government. Occupational demand changes in construction are likely to have an impact on each of these sectors. The model at present does not look beyond construction to explore skill requirement changes in such associated sectors. Hence, it is valuable at a later stage to identify these relationships so as to, for instance, make more explicit impact of planned changes in the manufacturing sector on construction manpower demand. The extension of these types of relationships will complicate the workings of the model, but such an extension should produce a greater body of information for those planning employment and training.

In addition, international dimensions of the forecasting model could be extended. Increasing construction demand in developing cities such as Macau, Shenzhen and Guangzhou has been apparent recently. A significant international movement of construction manpower is observed in these neighbouring areas. It is likely to be considerable flows in both directions in future. The major concern is with the direction of the net flow and any resulting change in the skill composition. It will become important to model the flows and to integrate such a migration model into the main manpower demand forecasting framework. Obviously much data would be required to serve such an exercise and co-operation and intensive cross-border/cross-country construction planning authorities would be required. Looking well into the future, therefore it may be necessary to taken into account the international factors to produce a more comprehensive and meaningful manpower forecasting practice.

At the project level, the forecasting models developed in this study cover merely the site operatives owing to the data availability. It is therefore valuable to assess the demand for other construction personnel involved in a construction project including various technicians and professionals. The manpower demand for construction work in the private sector should also be assessed. However, these extensions, yet again, can only be carried out when the relevant data is available.

Future developments in manpower forecasting are inevitably linked to development in information technology (Bartholomew *et al.*, 1991). It is anticipated that, given the improvement of the time series data available, econometrics modelling techniques and the advanced development in information technology and statistical software packages, improved modelling capability can be realised. Such developments will make manpower planning more accessible and accurate at every level of the society.

8.6 SUMMARY

In order to maintain the competitiveness and vitality of the local construction industry, it is crucial to ensure the availability of adequate manpower with appropriate quality and skills. Training and lifelong learning policies should in advance respond promptly to the changing demand for skills and qualifications. This research was therefore initiated with the aim to develop robust models for forecasting the construction manpower demand, at project level and industry level. It is not only timely to focus on the prospects of skill requirements in the construction industry from the point of view of the changing nature of the industry, but also timely from the point of view that little research has been conducted in this area. New methods are now accessible and there very real possibility of developing an elusive model that will address the complexities of the skill demand behaviour, and accurately forecast future levels of specific skill needs in construction.

This chapter recaptures the key findings and conclusions of the research, from the literature review to the model development. In addition, value and limitations of the research are highlighted. Finally, recommendations for further research are put forward. This research not only enriches the knowledge in the subject of manpower forecasting, but also improves on the methodology for collating and compiling construction manpower statistics so as to facilitate manpower planning in the long run. A consistent basis is provided to foresee the trend of occupational demand and formulate policies and training programmes tailored to deal effectively with labour resource requirements in this critical sector of the economy. It is anticipated that continuous effort in researching and developing manpower forecasting system could undoubtedly contribute to the facilitation of the sustainable development of the economy.

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APPENDICES

Appendix A	Form GF527
Appendix B	Job Descriptions for broad occupations
Appendix C	Training Routes in Construction
Appendix D	Sample of Questionnaire
Appendix E	Results of Multiple Regression Analysis of Project-based
Appendix F	Rseults of Aggregate Manpower Demand Model
Appendix G	The Box-Jenkins Approach
Appendix H	Results of Multiple Regression Analysis of Broad Occupational Share Models
Appendix I	Revised Forecasting Models
Appendix J	Forecasts of Key Variables

APPENDIX A FORM GF527

Original - to C&SD
Duplicate - to Project Office

Triplicate - filed as Site Record
Quadruplicate - kept by Contractor

Monthly Return of Site Labour Deployment and Wage Rates for Construction Works

Dept/Div : _________/__________ Month/Year: _____/_____ Contract No. : _________________________ Contract Title : ____________________________________ Contractor : ______________________________ ☐# Nominated Sub-contractor Works Code[7] : ________________

Item No.	Trade	Trade List[1]		Number of workers engaged on site on each calendar day[b,c]																															Total Man-days	Overtime[d] (hours)	Daily Wage Rate ($)[e]			Item No.
		Orig.	Rev. (Code[2])	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31			Av.	High	Low	
1	Bar Bender & Fixer [or Steelbender][6]	✓	C304																																					1
2	Concretor	✓	C309																																					2
3	Drainlayer	✓	C314																																					3
4	Plumber	✓	C338																																					4
5	Leveller	---	C323																																					5
6	Bamboo Scaffolder	✓	C303																																					6
7	Carpenter & Joiner[3]	✓	---	(No. of workers/total man-days/overtime need not be entered. The total of Items 8 and 9 below will be adopted by C&SD in the compilation of labour wage indices. Please enter daily wage rates where applicable.)																																				7
8	Carpenter (Formwork)	---	C307																																					8
9	Joiner	---	C322																																					9
10	Plant & Equipment Operator (Load Shifting) [or Plant Operator (exc. driver, bulldozer driver, etc.)][6]	✓	C333																																					10
11	Truck Driver	✓	C349																																					11
12	Rock-Breaking Driller [or Pneumatic Driller][6]	✓	C339																																					12
13	Blacksmith[3]	✓	---	(No. of workers/total man-days/overtime need not be entered. The total of Items 14 and 15 below will be adopted by C&SD in the compilation of labour wage indices. Please enter daily wage rates where applicable.)																																				13
14	General Welder	---	C318																																					14
15	Metal Worker	---	C328																																					15
16	Glazier	✓	C319																																					16
17	Excavator (male)	✓																																						17
18	Excavator (female)	✓																																						18
19	Labourer (male)	✓																																						19
20	Labourer (female)	✓	C406																																					20
21	Concretor's Labourer (male)	✓																																						21
22	Concretor's Labourer (female)	✓																																						22
23	Heavy Load Labourer [or Heavy Load Coolie][6]	✓																																						23
24	Diver's Linesman	✓																																						24
25	Painter & Decorator	✓	C329																																					25
26	Plasterer	✓	C337																																					26
27	Terrazzo & Granolithic Worker	✓																																						27
28	Plasterer's Labourer (male)	✓	---																																					28
29	Plasterer's Labourer (female)	✓	---																																					29
30	Bricklayer	✓	C305																																					30
31	Bricklayer's Labourer (male)	✓	---																																					31
32	Bricklayer's Labourer (female)	✓	---																																					32
33	Marble Worker	---	C324																																					33
34	Mason (incl. rubble mason, splitting mason and ashlar mason)	✓	C326																																					34
35	Structural Steel Welder	---	C346																																					35
36	Structural Steel Erector	✓	C345																																					36
37	Rigger/Metal Formwork Erector	---	C341																																					37
38	Asphalter (Road Construction)	---	C302																																					38
39	Construction Plant Mechanic [or Fitter][6]	✓	C310																																					39
40	Diver	✓	C313																																					40
41	Electrical Fitter (incl. Electrician)	✓	E305																																					41
42	Mechanical Fitter	---	E310																																					42
43	Refrigeration/AC/Ventilation Mechanic	---	E314																																					43
44	Fire Service Mechanic	---	E306																																					44
45	Lift and Escalator Mechanic	---	E309																																					45
46	Building Services Maintenance Mechanic	---	E302																																					46
47	Cable Jointer (Power)	---	E303																																					47
48	Others[4]: trade name - code -																																							48
49	Others[4]: trade name - code -																																							49
50	Others[4]: trade name - code -																																							50
51	Others[4]: trade name - code -																																							51
52	Others[4]: trade name - code -																																							52
	Completed by Agent of Contractor																																							
	Checked by IOW/COW																																							

Tick in the box only for a nominated sub-contractor

APPENDIX B JOB DESCRIPTIONS FOR BROAD OCCUPATIONS

Source: *Quarterly General Household Survey*, Census and Statistics Department, HKSAR Government.

Occupation refers to the kind of work, nature of duties and main task performed by a person in his/her main job during the seven days before enumeration. The classification used basically follows the major group of the International Standard Classification of Occupations (ILO, 1990), with adaptation for Hong Kong.

Managers and administrators **–** including administrators, commissioners and directors in government service; consuls; councillors; directors, chief executive officers, presidents, general managers, functional managers, branch managers and small business managers in industry, commerce, import and export trades, wholesale and retail trades, catering and lodging services, transport, electricity, gas, water and other services and agricultural and fishery sectors.

Professionals **–** including qualified professional scientists, doctors, dentists and other medical professionals; architects, surveyors and engineers; vice-chancellors, directors, academic staff and administrators of university and post-secondary college; principals and teachers of secondary school; statisticians; mathematicians; system analysts and computer programmers; lawyers and judges; accountants; business consultants and analysts; social workers; translators and interpreters; news editors and journalists; writers; librarians and members of religious orders.

***Associate professionals* –** including science technicians, nurses and midwives, dental assistants and other health associate professionals; architectural, surveying and engineering technicians; optical and electronic equipment controllers; ship pilots and air traffic controllers; principals and teachers of primary school and kindergarten/nursery, statistical assistants; computer operators; law clerks; accounting supervisors; public relation officer; sales representatives; designers; estate managers; social work assistants; superintendents, inspectors and officers of the police and other discipline services; performers and sportsmen.

***Clerks* –** including stenographers, secretaries and typists; bookkeeping, finance, shipping, filing and personnel clerks; cashiers and tellers; receptionists and information clerks.

***Service workers and shop sales workers* –** including air hostesses and travel guides; house stewards; cooks and waiters; baby-sisters; hairdressers and beauticians; rank and file of the police and other discipline services; transport conductors and other service workers; wholesale and retail salesmen in shops; shop assistants and fashion models.

***Craft and related workers* –** including miners and quarrymen; bricklayers, carpenters and other construction workers; metal moulders; blacksmiths; machinery, electric and electronic instrument mechanics; jewellery workers and watch makers; potters; typesetters; bakers, food and beverage processors; painters; craft workers in textile, garment, leather, rubber and plastic trades and other craft workers.

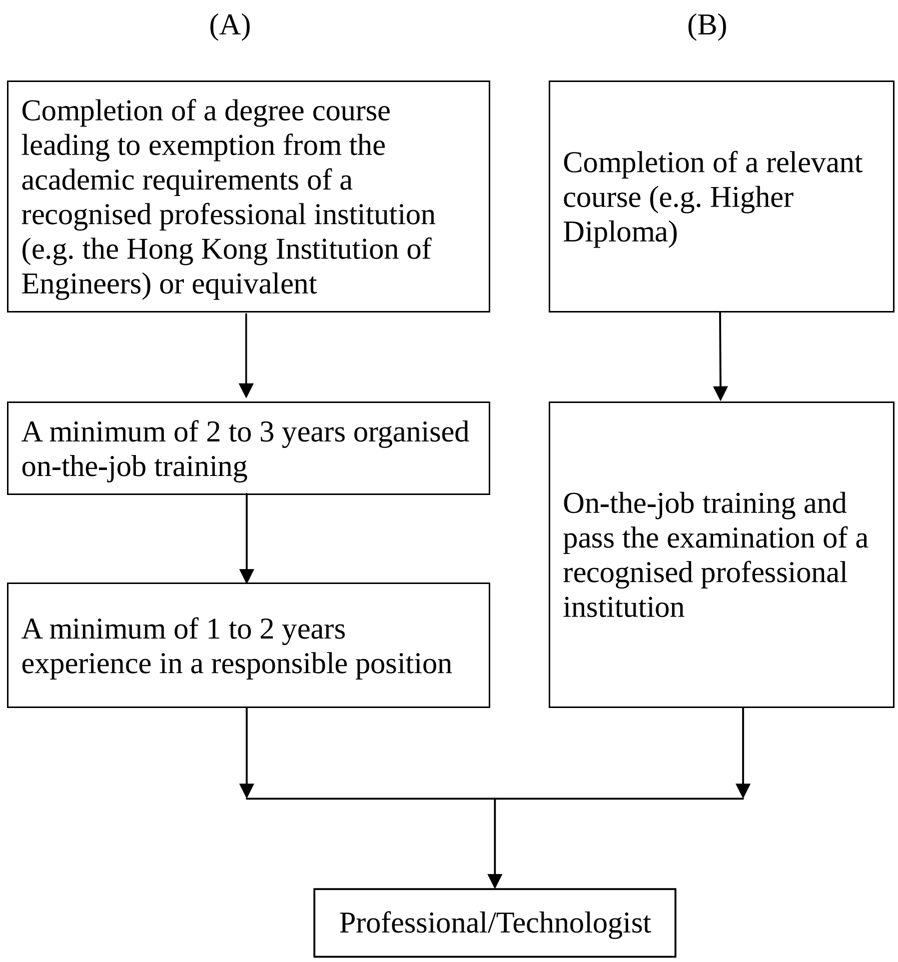
Plant and machine operators and assemblers **–** including well drillers and borers; ore smelting furnace operators; brick and tile kilnmen; sawmill sawyers; paper makers; chemical processing plant operators; power-generating plant and boiler operators; asbestos cement products makers; metal finishers and electroplaters; dairy and other food processing machine operators; printing machine operators; machine operators for production of textile, rubber and plastic products; assemblers; drivers; seamen and other plant and machine operators.

Elementary occupations **–** including street vendors; domestic helpers and cleaners; messengers; private security guards; watchmen; freight handlers; lift operators; construction labourers; hand packers; agricultural and fishery labourers.

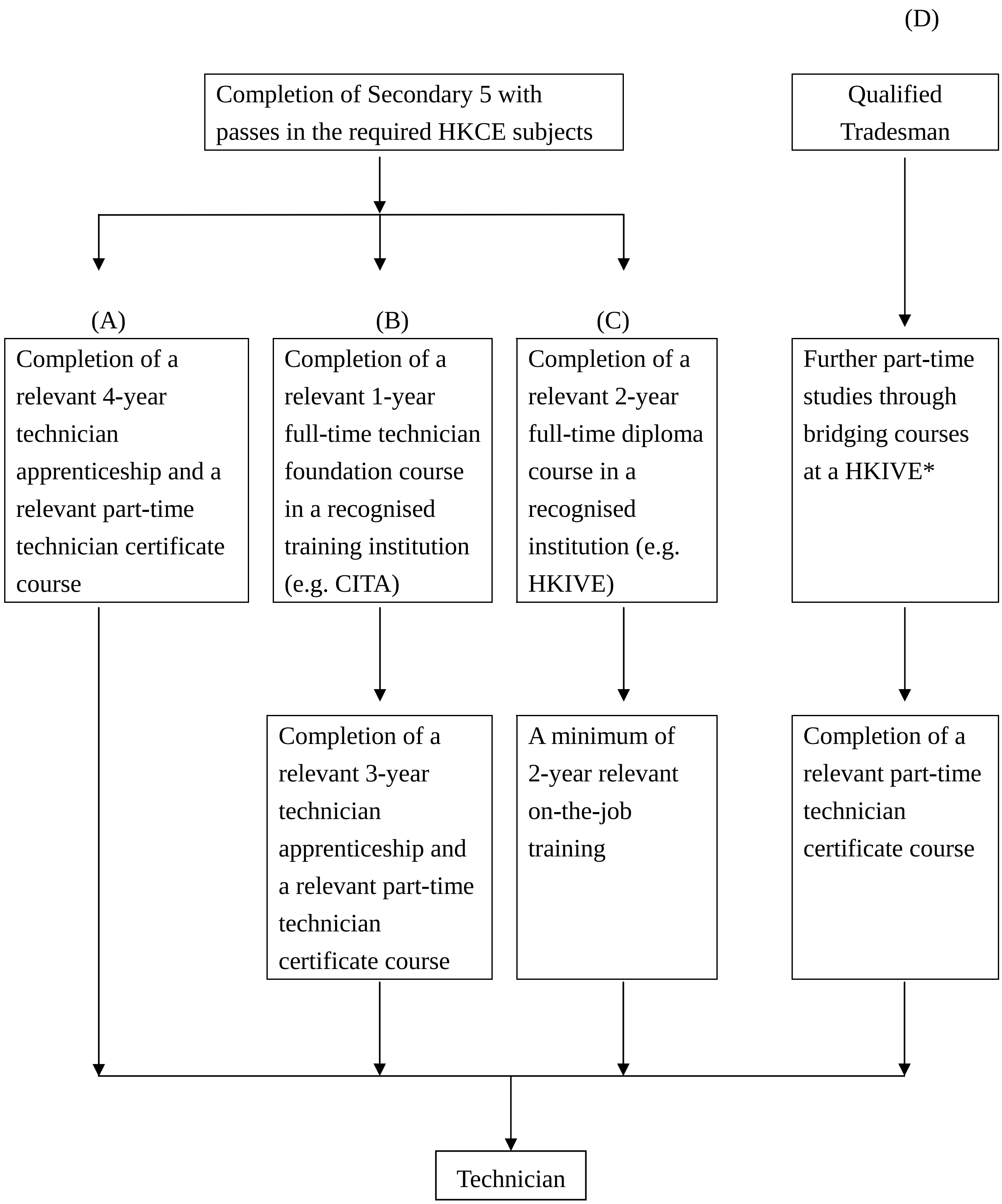
APPENDIX C TRAINING ROUTES IN CONSTRUCTION

Source: VTC (2003), *Manpower Survey Report of the Building & Civil Engineering Industry*, Hong Kong: the Vocational Training Council.

Training of Professionals/Technologists

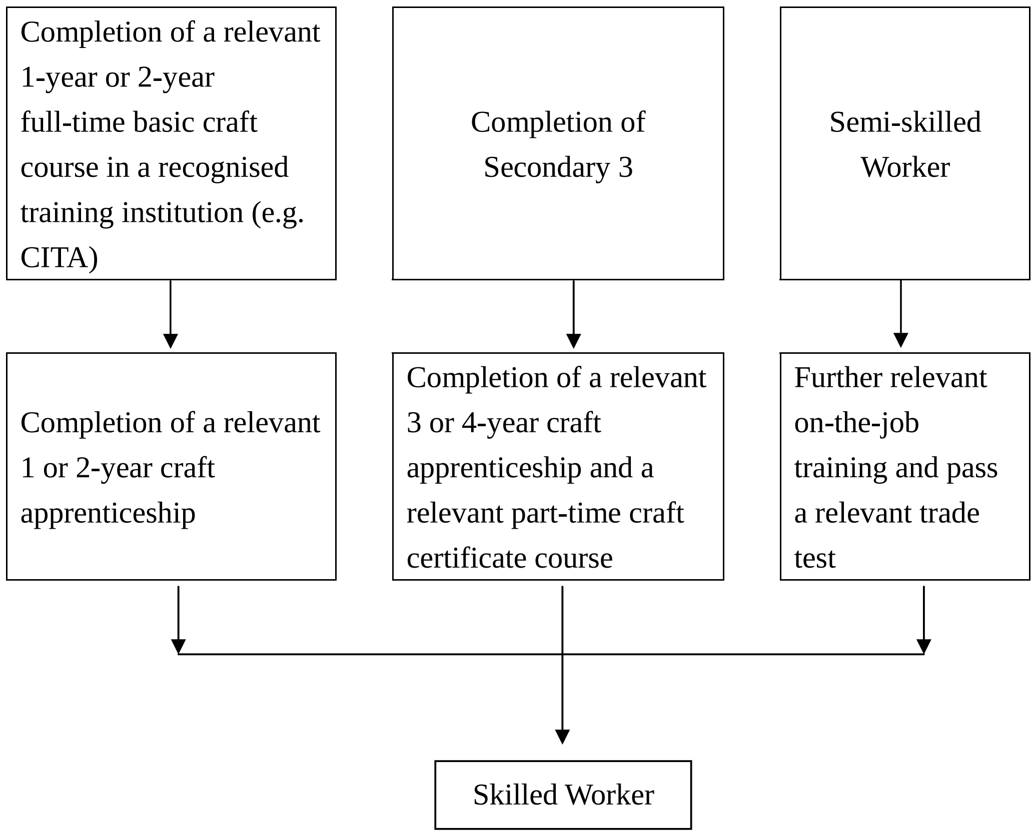


Training of Technicians



* The Hong Kong Institute of Vocational Education

Training of Skilled Workers



APPENDIX D SAMPLE OF QUESTIONNAIRE

THE HONG KONG POLYTECHNIC UNIVERSITY
DEPARTMENT OF BUILDING AND REAL ESTATE

QUESTIONNAIRE FOR Ph.D. RESEARCH PROJECT

Title: Forecasting Manpower Demand in the Construction Industry of Hong Kong

Contract no.: (given)

1. Project Type:

2. Final contract amount (HK$M):

3. Approximate percentage of the expenditure on mechanisation/automation (e.g. operational and control systems/ plant/ equipment) of the approx. revised project value (for construction):

☐ less than 5% ☐ 6-10%
☐ 11-15% ☐ 16-20%
☐ 21-25% ☐ 26-30%
☐ 31-35% ☐ 36-40%
☐ 41-45% ☐ 46-50%
☐ more than 50%

4. Approximate percentage of the material cost on E&M Services of the approx. revised project value (for construction) :

☐ less than 5% ☐ 6-10%
☐ 11-15% ☐ 16-20%
☐ 21-25% ☐ 26-30%
☐ 31-35% ☐ 36-40%
☐ 41-45% ☐ 46-50%
☐ more than 50%

5. Approximate percentage of off-site prefabrication of all construction product components (e.g. wall, staircases, external facades, floor slabs, door sets, etc.):

☐ less than 10% ☐ 11-20%
☐ 21-30% ☐ 31-40%
☐ 41-50% ☐ 51-60%
☐ 61-70% ☐ 71-80%
☐ 81-90% ☐ 91-100%

p.1

6. *Management*

What is your Impression on the main contractor's overall management of the project (1-extremely ineffective; 9-extremely effective)	extremely ineffective →								extremely effective	
	1 ☐	2 ☐	3 ☐	4 ☐	5 ☐	6 ☐	7 ☐	8 ☐	9 ☐	Don't know ☐

7. *Project Complexity*

Do you agree: (1- strongly disagree; 9-strongly disagree)	Strongly disagree →								Strongly agree
	1	2	3	4	5	6	7	8	9
a) The physical conditions of the construction site were complex.	☐	☐	☐	☐	☐	☐	☐	☐	☐
b) The level of buildability was low.	☐	☐	☐	☐	☐	☐	☐	☐	☐
c) The coordination works between the design and construction team was complicated.	☐	☐	☐	☐	☐	☐	☐	☐	☐
d) Overall project characteristics were technologically complex.	☐	☐	☐	☐	☐	☐	☐	☐	☐

End of the Questionnaire

p.2

APPENDIX E RESULTS OF MULTIPLE REGRESSION ANALYSIS OF PROJECT-BASED MODELS

Total labour demand

Model Summary[e]

M	R	R Squ	Adjusted R Square	Std. Error	Durbin -
1	.969[a]	.938	.937	.33677	
2	.971[b]	.944	.941	.32427	
3	.975[c]	.950	.947	.30785	
4	.976[d]	.953	.949	.30158	2.109

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Overall project characteristics were technologically complex
c. Predictors: (Constant), Approx. final contract amount (natural log), Overall project characteristics were technologically complex, The physical conditions of the construction site were complex
d. Predictors: (Constant), Approx. final contract amount (natural log), Overall project characteristics were technologically complex, The physical conditions of the construction site were complex, Project type
e. Dependent Variable: LNTOTAL

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.546	.154		42.573	.000		
	Approx. final contract amount (natural log)	.855	.032	.969	26.965	.000	1.000	1.000
2	(Constant)	6.708	.165		40.532	.000		
	Approx. final contract amount (natural log)	.874	.032	.991	27.462	.000	.918	1.089
	Overall project characteristics were technologically complex	-5.917E-02	.027	-.079	-2.185	.034	.918	1.089
3	(Constant)	6.531	.173		37.823	.000		
	Approx. final contract amount (natural log)	.870	.030	.986	28.727	.000	.915	1.093
	Overall project characteristics were technologically complex	-9.096E-02	.029	-.121	-3.166	.003	.735	1.360
	The physical conditions of the construction site were complex	6.328E-02	.026	.093	2.479	.017	.773	1.293
4	(Constant)	6.539	.169		38.645	.000		
	Approx. final contract amount (natural log)	.884	.031	1.002	28.744	.000	.852	1.174
	Overall project characteristics were technologically complex	-9.237E-02	.028	-.123	-3.280	.002	.735	1.361
	The physical conditions of the construction site were complex	5.872E-02	.025	.086	2.335	.024	.765	1.308
	Project type	-.178	.104	-.057	-1.713	.094	.924	1.082

a. Dependent Variable: LNTOTAL

Bar Bender and Fixer

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.760[a]	.577	.568	1.98714	
2	.778[b]	.605	.588	1.94072	
3	.810[c]	.656	.633	1.83152	
4	.829[d]	.686	.658	1.76874	
5	.842[e]	.708	.674	1.72598	2.147

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), The level of buildability was low
c. Predictors: (Constant), Approx. final contract amount (natural log), The level of buildability was low, The coordination works between the design and construction team was complicated
d. Predictors: (Constant), Approx. final contract amount (natural log), The level of buildability was low, The coordination works between the design and construction team was complicated, Approximate percentage of the material cost on E&M Services of the approx. revised project value
e. Predictors: (Constant), Approx. final contract amount (natural log), The level of buildability was low, The coordination works between the design and construction team was complicated, Approximate percentage of the material cost on E&M Services of the approx. revised project value, Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value
f. Dependent Variable: LNT2

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-.397	.907		-.437	.664		
	Approx. final contract amount (natural log)	1.499	.187	.760	8.010	.000	1.000	1.000
2	(Constant)	.709	1.076		.659	.513		
	Approx. final contract amount (natural log)	1.478	.183	.749	8.069	.000	.996	1.004
	The level of buildability was low	-.273	.151	-.168	-1.810	.077	.996	1.004
3	(Constant)	.616	1.016		.606	.548		
	Approx. final contract amount (natural log)	1.290	.188	.654	6.878	.000	.846	1.182
	The level of buildability was low	-.392	.150	-.241	-2.620	.012	.901	1.110
	The coordination works between the design and construction team was complicated	.351	.136	.254	2.579	.013	.790	1.266
4	(Constant)	.612	.982		.624	.536		
	Approx. final contract amount (natural log)	1.390	.188	.705	7.413	.000	.789	1.268
	The level of buildability was low	-.386	.144	-.238	-2.675	.010	.901	1.110
	The coordination works between the design and construction team was complicated	.404	.134	.292	3.015	.004	.761	1.314
	Approximate percentage of the material cost on E&M Services of the approx. revised project value	-.379	.184	-.189	-2.062	.045	.847	1.181
5	(Constant)	.169	.989		.171	.865		
	Approx. final contract amount (natural log)	1.429	.184	.724	7.755	.000	.778	1.286
	The level of buildability was low	-.337	.144	-.207	-2.346	.024	.867	1.153
	The coordination works between the design and construction team was complicated	.333	.137	.241	2.442	.019	.697	1.434
	Approximate percentage of the material cost on E&M Services of the approx. revised project value	-.540	.201	-.269	-2.691	.010	.677	1.477
	Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value	.368	.206	.178	1.791	.080	.688	1.454

a. Dependent Variable: LNT2

Plasterer

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.598[a]	.357	.344	2.66814	
2	.672[b]	.452	.429	2.49045	
3	.720[c]	.518	.487	2.36064	1.879

a. Predictors: (Constant), Project type
b. Predictors: (Constant), Project type, Approx. final contract amount (natural log)
c. Predictors: (Constant), Project type, Approx. final contract amount (natural log), The physical conditions of the construction site were complex
d. Dependent Variable: LNT5

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	3.592	.433		8.299	.000		
	Project type	4.566	.884	.598	5.168	.000	1.000	1.000
2	(Constant)	.562	1.139		.493	.624		
	Project type	3.979	.850	.521	4.680	.000	.941	1.063
	Approx. final contract amount (natural log)	.687	.242	.317	2.845	.007	.941	1.063
3	(Constant)	2.395	1.303		1.838	.073		
	Project type	3.708	.813	.486	4.562	.000	.925	1.082
	Approx. final contract amount (natural log)	.812	.234	.374	3.466	.001	.899	1.113
	The physical conditions of the construction site were complex	-.444	.177	-.264	-2.512	.016	.949	1.054

a. Dependent Variable: LNT5

Concreter

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.589[a]	.347	.334	2.02433	
2	.659[b]	.434	.410	1.90428	2.077

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Overall project characteristics were technologically complex
c. Dependent Variable: LNT9

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	Collinearity Statistics VIF
1	(Constant)	1.326	.924		1.435	.158		
	Approx. final contract amount (natural log)	.963	.190	.589	5.053	.000	1.000	1.000
2	(Constant)	2.495	.972		2.567	.013		
	Approx. final contract amount (natural log)	1.106	.187	.677	5.917	.000	.918	1.089
	Overall project characteristics were technologically complex	-.428	.159	-.308	-2.691	.010	.918	1.089

a. Dependent Variable: LNT9

Carpenter (Formwork)

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.936[a]	.876	.874	.63352	
2	.950[b]	.902	.898	.57032	
3	.954[c]	.909	.903	.55448	
4	.959[d]	.920	.912	.52797	
5	.964[e]	.929	.920	.50441	1.916

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Approximate percentage of off-site prefabrication of all construction product components
c. Predictors: (Constant), Approx. final contract amount (natural log), Approximate percentage of off-site prefabrication of all construction product components, The coordination works between the design and construction team was complicated
d. Predictors: (Constant), Approx. final contract amount (natural log), Approximate percentage of off-site prefabrication of all construction product components, The coordination works between the design and construction team was complicated, The physical conditions of the construction site were complex
e. Predictors: (Constant), Approx. final contract amount (natural log), Approximate percentage of off-site prefabrication of all construction product components, The coordination works between the design and construction team was complicated, The physical conditions of the construction site were complex, Approximate percentage of the material cost on E&M Services of the approx. revised project value
f. Dependent Variable: LNT7

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.992	.291		10.298	.000		
	Approx. final contract amount (natural log)	1.066	.060	.936	17.854	.000	1.000	1.000
2	(Constant)	3.447	.294		11.730	.000		
	Approx. final contract amount (natural log)	1.031	.055	.905	18.834	.000	.964	1.037
	Approximate percentage of off-site prefabrication of all construction product components	-.156	.046	-.163	-3.395	.001	.964	1.037
3	(Constant)	3.367	.289		11.656	.000		
	Approx. final contract amount (natural log)	.988	.058	.868	17.107	.000	.818	1.223
	Approximate percentage of off-site prefabrication of all construction product components	-.172	.045	-.179	-3.773	.000	.933	1.071
	The coordination works between the design and construction team was complicated	7.614E-02	.040	.094	1.884	.066	.840	1.190
4	(Constant)	3.771	.325		11.596	.000		
	Approx. final contract amount (natural log)	.998	.055	.877	18.092	.000	.813	1.230
	Approximate percentage of off-site prefabrication of all construction product components	-.182	.044	-.190	-4.176	.000	.924	1.082
	The coordination works between the design and construction team was complicated	.100	.040	.124	2.516	.016	.784	1.276
	The physical conditions of the construction site were complex	-.100	.043	-.108	-2.329	.025	.892	1.121
5	(Constant)	3.758	.311		12.093	.000		
	Approx. final contract amount (natural log)	1.031	.055	.905	18.848	.000	.755	1.324
	Approximate percentage of off-site prefabrication of all construction product components	-.174	.042	-.182	-4.182	.000	.918	1.089
	The coordination works between the design and construction team was complicated	.116	.039	.144	2.993	.005	.758	1.319
	The physical conditions of the construction site were complex	-9.894E-02	.041	-.107	-2.412	.020	.892	1.121
	Approximate percentage of the material cost on E&M Services of the approx. revised project value	-.118	.053	-.102	-2.240	.031	.843	1.186

a. Dependent Variable: LNT7

Plant and Equipment Operator (Earthmoving Machinery)

Model Summary[f]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.701[a]	.492	.481	1.40751	
2	.831[b]	.690	.676	1.11149	
3	.874[c]	.763	.747	.98234	
4	.888[d]	.789	.770	.93755	
5	.899[e]	.807	.784	.90704	1.802

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Project type
c. Predictors: (Constant), Approx. final contract amount (natural log), Project type, Approximate percentage of off-site prefabrication of all construction product components
d. Predictors: (Constant), Approx. final contract amount (natural log), Project type, Approximate percentage of off-site prefabrication of all construction product components, The physical conditions of the construction site were complex
e. Predictors: (Constant), Approx. final contract amount (natural log), Project type, Approximate percentage of off-site prefabrication of all construction product components, The physical conditions of the construction site were complex, Approximate percentage of the material cost on E&M Services of the approx. revised project value
f. Dependent Variable: LNT11

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3.314	.644		5.144	.000		
	Approx. final contract amount (natural log)	.891	.133	.701	6.672	.000	1.000	1.000
2	(Constant)	3.195	.509		6.276	.000		
	Approx. final contract amount (natural log)	1.022	.108	.804	9.442	.000	.949	1.054
	Project type	-2.101	.392	-.457	-5.363	.000	.949	1.054
3	(Constant)	4.041	.505		8.002	.000		
	Approx. final contract amount (natural log)	.948	.098	.746	9.701	.000	.909	1.100
	Project type	-1.978	.348	-.430	-5.685	.000	.940	1.064
	Approximate percentage of off-site prefabrication of all construction product components	-.292	.079	-.277	-3.689	.001	.956	1.046
4	(Constant)	3.339	.570		5.856	.000		
	Approx. final contract amount (natural log)	.906	.095	.713	9.531	.000	.876	1.142
	Project type	-1.858	.336	-.404	-5.526	.000	.918	1.090
	Approximate percentage of off-site prefabrication of all construction product components	-.286	.076	-.271	-3.778	.000	.954	1.048
	The physical conditions of the construction site were complex	.164	.071	.166	2.303	.026	.945	1.059
5	(Constant)	3.286	.552		5.950	.000		
	Approx. final contract amount (natural log)	.990	.101	.779	9.780	.000	.723	1.384
	Project type	-2.047	.339	-.445	-6.040	.000	.845	1.184
	Approximate percentage of off-site prefabrication of all construction product components	-.262	.074	-.248	-3.533	.001	.929	1.076
	The physical conditions of the construction site were complex	.168	.069	.171	2.449	.019	.944	1.060
	Approximate percentage of the material cost on E&M Services of the approx. revised project value	-.195	.098	-.151	-1.985	.054	.788	1.269

a. Dependent Variable: LNT11

Excavator

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.603[a]	.363	.345	2.98158	
2	.699[b]	.449	.418	2.85268	
3	.764[c]	.498	.473	2.74950	2.139

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Project type
c. Predictors: (Constant), Approx. final contract amount (natural log), Project type, Overall project characteristics were technologically complex
d. Dependent Variable: LNT20

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-.698	1.361		-.513	.610		
	Approx. final contract amount (natural log)	.857	.281	.403	3.053	.004	1.000	1.000
2	(Constant)	-.521	1.305		-.399	.692		
	Approx. final contract amount (natural log)	.700	.277	.330	2.530	.015	.941	1.063
	Project type	2.270	.974	.304	2.331	.024	.941	1.063
3	(Constant)	.815	1.403		.580	.564		
	Approx. final contract amount (natural log)	.878	.279	.413	3.143	.003	.858	1.165
	Project type	2.099	.942	.281	2.228	.031	.934	1.070
	Overall project characteristics were technologically complex	-.494	.230	-.273	-2.143	.037	.912	1.097

a. Dependent Variable: LNT20

Labourer

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.845[a]	.713	.707	.66568	
2	.923[b]	.853	.846	.48243	
3	.933[c]	.871	.863	.45584	2.138

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Project type
c. Predictors: (Constant), Approx. final contract amount (natural log), Project type, Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value
d. Dependent Variable: LNT22

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.320	.304		20.794	.000		
	Approx. final contract amount (natural log)	.685	.063	.845	10.932	.000	1.000	1.000
2	(Constant)	6.235	.221		28.255	.000		
	Approx. final contract amount (natural log)	.760	.047	.938	16.250	.000	.941	1.063
	Project type	-1.097	.165	-.385	-6.663	.000	.941	1.063
3	(Constant)	6.371	.215		29.618	.000		
	Approx. final contract amount (natural log)	.772	.044	.953	17.372	.000	.931	1.074
	Project type	-1.017	.159	-.357	-6.411	.000	.905	1.105
	Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value	-.119	.046	-.141	-2.578	.013	.940	1.064

a. Dependent Variable: LNT22

Metal Worker/Welder

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.689[a]	.474	.463	2.09618	
2	.715[b]	.511	.490	2.04259	1.867

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), Project type
c. Dependent Variable: LNT26

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-4.241E-02	.957		-.044	.965		
	Approx. final contract amount (natural log)	1.298	.197	.689	6.581	.000	1.000	1.000
2	(Constant)	6.044E-02	.934		.065	.949		
	Approx. final contract amount (natural log)	1.208	.198	.641	6.094	.000	.941	1.063
	Project type	1.314	.697	.198	1.885	.066	.941	1.063

a. Dependent Variable: LNT26

Truck Driver

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.779[a]	.607	.599	1.95186	
2	.832[b]	.693	.680	1.74406	
3	.849[c]	.721	.702	1.68199	2.212

a. Predictors: (Constant), Project type
b. Predictors: (Constant), Project type, Approx. final contract amount (natural log)
c. Predictors: (Constant), Project type, Approx. final contract amount (natural log), The level of buildability was low
d. Dependent Variable: LNT29

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.981	.321		21.756	.000		
	Project type	-5.527	.648	-.779	-8.523	.000	1.000	1.000
2	(Constant)	4.304	.799		5.383	.000		
	Project type	-6.072	.599	-.856	-10.137	.000	.936	1.069
	Approx. final contract amount (natural log)	.612	.171	.303	3.587	.001	.936	1.069
3	(Constant)	3.192	.934		3.418	.001		
	Project type	-6.096	.578	-.859	-10.550	.000	.935	1.069
	Approx. final contract amount (natural log)	.632	.165	.313	3.835	.000	.932	1.072
	The level of buildability was low	.275	.130	.167	2.111	.040	.997	1.003

a. Dependent Variable: LNT29

Electrician/Electrical Fitter

Model Summary[e]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.413[a]	.171	.154	2.56949	
2	.474[b]	.225	.192	2.51057	
3	.529[c]	.280	.233	2.44640	
4	.579[d]	.335	.276	2.37633	1.790

a. Predictors: (Constant), Approx. final contract amount (natural log)
b. Predictors: (Constant), Approx. final contract amount (natural log), The physical conditions of the construction site were complex
c. Predictors: (Constant), Approx. final contract amount (natural log), The physical conditions of the construction site were complex, Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value
d. Predictors: (Constant), Approx. final contract amount (natural log), The physical conditions of the construction site were complex, Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value, The level of buildability was low
e. Dependent Variable: LNT32

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2.335	1.173		1.990	.052		
	Approx. final contract amount (natural log)	.760	.242	.413	3.144	.003	1.000	1.000
2	(Constant)	3.744	1.385		2.702	.010		
	Approx. final contract amount (natural log)	.841	.240	.457	3.498	.001	.966	1.036
	The physical conditions of the construction site were complex	-.337	.186	-.237	-1.811	.077	.966	1.036
3	(Constant)	3.293	1.371		2.401	.020		
	Approx. final contract amount (natural log)	.778	.237	.423	3.284	.002	.946	1.057
	The physical conditions of the construction site were complex	-.348	.182	-.244	-1.919	.061	.965	1.037
	Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value	.456	.244	.237	1.870	.068	.976	1.025
4	(Constant)	2.251	1.437		1.567	.124		
	Approx. final contract amount (natural log)	.832	.232	.452	3.590	.001	.932	1.073
	The physical conditions of the construction site were complex	-.479	.189	-.336	-2.538	.015	.841	1.189
	Approximate percentage of the expenditure on mechanisation/automation of the approx. revised project value	.493	.238	.256	2.074	.044	.970	1.031
	The level of buildability was low	.382	.197	.253	1.937	.059	.865	1.156

a. Dependent Variable: LNT32

APPENDIX F RESULTS OF AGGREGATE MANPOWER DEMAND MODEL

Cointegration Analysis

Sample: 1983:1 2002:4
Included observations: 74
Test assumption: Linear deterministic trend in the data
Series: MD Q RW MP BR LP
Lags interval: 1 to 5

Eigenvalue	Likelihood Ratio	5 Percent Critical Value	1 Percent Critical Value	Hypothesized No. of CE(s)
0.473304	115.2070	94.15	103.18	None **
0.300054	67.76331	68.52	76.07	At most 1
0.217119	41.36365	47.21	54.46	At most 2
0.154714	23.25037	29.68	35.65	At most 3
0.133138	10.81245	15.41	20.04	At most 4
0.003234	0.239682	3.76	6.65	At most 5

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
L.R. test indicates 1 cointegrating equation(s) at 5% significance level

Unnormalized Cointegrating Coefficients:

MD	Q	RW	MP	BR	LP
5.201633	-6.680320	-4.194132	2.152024	0.065987	3.986988
-2.978404	4.494019	1.628831	-1.786490	-0.321312	-4.299496
-5.364173	3.890799	-2.172584	2.246885	0.497985	-7.005172
-0.663736	-1.470057	-0.212317	0.859794	0.094183	0.281487
1.612524	-1.130957	1.946124	-0.692393	0.425525	1.413262
-4.411981	4.709676	-1.863084	0.782758	0.548106	-5.066049

Normalized Cointegrating Coefficients: 1 Cointegrating Equation(s)

MD	Q	RW	MP	BR	LP	C
1.000000	-1.284274	-0.806311	0.413721	0.012686	0.766488	-0.626312
	(0.09614)	(0.21516)	(0.12954)	(0.00816)	(0.09410)	
Log likelihood	909.4310					

Vector Error Correction Model

Sample(adjusted): 1984:3 2002:4
Included observations: 74 after adjusting endpoints
Standard errors & t-statistics in parentheses

Cointegrating Eq:	CointEq1
MD(-1)	1.000000
Q(-1)	-1.284274 (0.09614) (-13.3587)
RW(-1)	-0.806311 (0.21516) (-3.74742)
MP(-1)	0.413721 (0.12954) (3.19385)
BR(-1)	0.012686 (0.00816) (1.55492)
LP(-1)	0.766488 (0.09410) (8.14537)
C	-0.626312

Error Correction:	D(MD)	D(Q)	D(RW)	D(MP)	D(BR)	D(LP)
CointEq1	-0.200972 (0.14859) (-1.35253)	0.136314 (0.25916) (0.52599)	0.996988 (0.21113) (4.72223)	0.151495 (0.08068) (1.87772)	-1.406644 (1.02258) (-1.37559)	0.046746 (0.32020) (0.14599)
D(MD(-1))	0.406119 (0.28134) (1.44352)	-0.014110 (0.41813) (-0.03375)	-1.019107 (0.34063) (-2.99179)	-0.105999 (0.13017) (-0.81431)	3.408443 (1.64984) (2.06593)	-0.754483 (0.51661) (-1.46046)
D(MD(-2))	0.287943 (0.28560) (1.00820)	0.172483 (0.42446) (0.40635)	-0.802819 (0.34579) (-2.32166)	-0.062227 (0.13214) (-0.47091)	-0.097185 (1.67483) (-0.05803)	-0.106157 (0.52443) (-0.20242)
D(MD(-3))	0.203745 (0.25482) (0.79955)	-0.083363 (0.37872) (-0.22012)	-0.882500 (0.30853) (-2.86032)	0.002006 (0.11790) (0.01702)	1.716450 (1.49435) (1.14863)	-0.273531 (0.46792) (-0.58457)
D(MD(-4))	0.601557 (0.25493) (2.35968)	-0.104363 (0.37888) (-0.27545)	-0.482132 (0.30866) (-1.56201)	-0.031638 (0.11795) (-0.26822)	0.956855 (1.49498) (0.64005)	-0.591304 (0.46812) (-1.26316)
D(MD(-5))	0.452837 (0.23805) (1.90228)	-0.244985 (0.35379) (-0.69245)	-0.302616 (0.28822) (-1.04994)	-0.198338 (0.11014) (-1.80076)	1.102509 (1.39598) (0.78978)	-0.699857 (0.43712) (-1.60107)

Error Correction:	D(MD)	D(Q)	D(RW)	D(MP)	D(BR)	D(LP)
D(Q(-1))	-0.428587	-0.108241	1.517879	0.266801	-2.698790	0.452247
	(0.27597)	(0.41014)	(0.33413)	(0.12768)	(1.61833)	(0.50674)
	(-1.55304)	(-0.26391)	(4.54279)	(2.08954)	(-1.66764)	(0.89246)
D(Q(-2))	-0.123209	0.085293	1.224899	0.141114	0.476287	0.016279
	(0.31829)	(0.47305)	(0.38538)	(0.14727)	(1.86655)	(0.58447)
	(-0.38709)	(0.18030)	(3.17843)	(0.95821)	(0.25517)	(0.02785)
D(Q(-3))	-0.132137	-0.147354	1.119638	0.087746	-1.946953	-0.164532
	(0.30081)	(0.44707)	(0.36421)	(0.13918)	(1.76404)	(0.55237)
	(-0.43926)	(-0.32960)	(3.07412)	(0.63044)	(-1.10369)	(-0.29787)
D(Q(-4))	-0.386250	0.345020	1.091725	0.151598	-1.721416	0.528700
	(0.29169)	(0.43351)	(0.35316)	(0.13496)	(1.71053)	(0.53561)
	(-1.32418)	(0.79587)	(3.09126)	(1.12329)	(-1.00637)	(0.98710)
D(Q(-5))	-0.603299	0.194908	0.362549	0.160215	-1.062434	0.913086
	(0.24846)	(0.36926)	(0.30082)	(0.11496)	(1.45699)	(0.45622)
	(-2.42820)	(0.52784)	(1.20521)	(1.39372)	(-0.72920)	(2.00140)
D(RW(-1))	-0.036204	-0.031003	-0.127378	0.038155	0.698664	-0.103562
	(0.13106)	(0.19479)	(0.15869)	(0.06064)	(0.76859)	(0.24066)
	(-0.27623)	(-0.15916)	(-0.80270)	(0.62920)	(0.90903)	(-0.43032)
D(RW(-2))	-0.102961	0.036896	-0.142681	0.050318	0.038658	0.055683
	(0.12487)	(0.18558)	(0.15118)	(0.05777)	(0.73225)	(0.22929)
	(-0.82456)	(0.19882)	(-0.94376)	(0.87096)	(0.05279)	(0.24285)
D(RW(-3))	0.161576	-0.005473	-0.236009	-0.023626	0.335934	-0.234955
	(0.11252)	(0.16723)	(0.13623)	(0.05206)	(0.65984)	(0.20661)
	(1.43599)	(-0.03273)	(-1.73239)	(-0.45382)	(0.50912)	(-1.13718)
D(RW(-4))	0.048569	0.043044	-0.122973	-0.034575	0.237603	0.028085
	(0.11680)	(0.17359)	(0.14142)	(0.05404)	(0.68496)	(0.21448)
	(0.41582)	(0.24796)	(-0.86955)	(-0.63977)	(0.34689)	(0.13094)
D(RW(-5))	-0.012908	0.038968	0.096482	-0.087274	0.292852	0.049033
	(0.09735)	(0.14468)	(0.11786)	(0.04504)	(0.57085)	(0.17875)
	(-0.13260)	(0.26935)	(0.81861)	(-1.93772)	(0.51301)	(0.27431)
D(MP(-1))	-0.207404	-0.615026	0.057331	0.383435	-2.494971	-0.355991
	(0.36502)	(0.54250)	(0.44195)	(0.16889)	(2.14057)	(0.67027)
	(-0.56820)	(-1.13369)	(0.12972)	(2.27034)	(-1.16556)	(-0.53112)
D(MP(-2))	0.379477	0.530101	-0.538676	0.218456	3.884635	0.361442
	(0.37770)	(0.56134)	(0.45730)	(0.17475)	(2.21491)	(0.69355)
	(1.00471)	(0.94435)	(-1.17794)	(1.25008)	(1.75385)	(0.52115)
D(MP(-3))	0.564654	0.301426	-0.549356	-0.172355	1.074921	-0.324404
	(0.39738)	(0.59058)	(0.48113)	(0.18386)	(2.33030)	(0.72968)
	(1.42096)	(0.51039)	(-1.14181)	(-0.93744)	(0.46128)	(-0.44459)
D(MP(-4))	-0.558649	0.454291	0.196090	-0.054759	2.317845	1.210034
	(0.37525)	(0.55770)	(0.45434)	(0.17362)	(2.20056)	(0.68905)
	(-1.48873)	(0.81458)	(0.43159)	(-0.31539)	(1.05330)	(1.75608)

Error Correction:	D(MD)	D(Q)	D(RW)	D(MP)	D(BR)	D(LP)
D(MP(-5))	0.044054	-0.531321	-0.452664	0.088807	-0.653117	-0.297038
	(0.36801)	(0.54695)	(0.44558)	(0.17027)	(2.15812)	(0.67576)
	(0.11971)	(-0.97143)	(-1.01590)	(0.52155)	(-0.30263)	(-0.43956)
D(BR(-1))	0.013808	-0.031788	-0.021962	-0.000901	-0.055939	-0.032438
	(0.02808)	(0.04173)	(0.03400)	(0.01299)	(0.16466)	(0.05156)
	(0.49178)	(-0.76176)	(-0.64603)	(-0.06933)	(-0.33973)	(-0.62915)
D(BR(-2))	-0.009002	0.004687	-0.020211	0.002910	-0.188203	0.027430
	(0.02595)	(0.03857)	(0.03142)	(0.01201)	(0.15219)	(0.04766)
	(-0.34684)	(0.12150)	(-0.64320)	(0.24231)	(-1.23660)	(0.57559)
D(BR(-3))	0.028447	0.062706	0.073609	-0.031141	0.176806	0.034742
	(0.02581)	(0.03836)	(0.03125)	(0.01194)	(0.15134)	(0.04739)
	(1.10225)	(1.63483)	(2.35568)	(-2.60796)	(1.16824)	(0.73311)
D(BR(-4))	-0.062783	-0.041292	0.021671	-0.006869	-0.314193	0.042906
	(0.02771)	(0.04119)	(0.03355)	(0.01282)	(0.16252)	(0.05089)
	(-2.26541)	(-1.00251)	(0.64585)	(-0.53567)	(-1.93327)	(0.84313)
D(BR(-5))	-0.007724	-0.022984	0.020541	-0.005575	-0.071369	0.002858
	(0.03014)	(0.04480)	(0.03649)	(0.01395)	(0.17675)	(0.05535)
	(-0.25628)	(-0.51309)	(0.56289)	(-0.39979)	(-0.40379)	(0.05165)
D(LP(-1))	0.366092	-0.109125	-0.931628	-0.168661	2.339669	-0.752853
	(0.19236)	(0.28589)	(0.23290)	(0.08900)	(1.12805)	(0.35322)
	(1.90314)	(-0.38170)	(-4.00005)	(-1.89503)	(2.07408)	(-2.13138)
D(LP(-2))	0.069440	-0.046655	-0.616760	-0.096244	-0.095377	-0.165987
	(0.22699)	(0.33735)	(0.27483)	(0.10502)	(1.33110)	(0.41680)
	(0.30592)	(-0.13830)	(-2.24418)	(-0.91641)	(-0.07165)	(-0.39824)
D(LP(-3))	0.130938	0.192900	-0.665057	0.010919	1.614780	-0.042947
	(0.21456)	(0.31887)	(0.25977)	(0.09927)	(1.25820)	(0.39398)
	(0.61028)	(0.60494)	(-2.56013)	(0.10999)	(1.28341)	(-0.10901)
D(LP(-4))	0.487822	-0.087382	-0.623991	-0.076264	0.589020	-0.571040
	(0.21579)	(0.32071)	(0.26127)	(0.09984)	(1.26542)	(0.39624)
	(2.26066)	(-0.27247)	(-2.38833)	(-0.76385)	(0.46547)	(-1.44115)
D(LP(-5))	0.449599	-0.031501	-0.115271	-0.104293	0.574410	-0.530822
	(0.18750)	(0.27866)	(0.22701)	(0.08675)	(1.09952)	(0.34429)
	(2.39790)	(-0.11304)	(-0.50777)	(-1.20221)	(0.52242)	(-1.54179)
C	0.000195	0.001138	0.018768	0.003623	-0.090831	-0.002001
	(0.00632)	(0.00939)	(0.00765)	(0.00292)	(0.03704)	(0.01160)
	(0.03090)	(0.12124)	(2.45427)	(1.23965)	(-2.45235)	(-0.17250)
R-squared	0.482559	0.528965	0.725992	0.647140	0.532538	0.523290
Sum sq. resids	0.047200	0.104256	0.069192	0.010104	1.623159	0.159148
S.E. equation	0.033523	0.049823	0.040589	0.015511	0.196587	0.061557
F-statistic	1.263507	1.521464	3.589681	2.484750	1.543449	1.487220
Log likelihood	167.2234	137.9024	153.0712	224.2567	36.32711	122.2521
Akaike AIC	-3.654688	-2.862227	-3.272193	-5.196126	-0.116949	-2.439246
Schwarz SC	-2.658335	-1.865875	-2.275841	-4.199774	0.879403	-1.442893
Determinant Residual Covariance		8.52E-19				
Log Likelihood		909.4310				
Akaike Information Criteria		-19.22787				
Schwarz Criteria		-13.06294				

APPENDIX G THE BOX-JENKINS APPROACH

The Box and Jenkins approach is a systematic tactic for identifying characteristics of a time series such as stationary and seasonality. It relies on iterative approach for identifying a useful model amongst a general class of possible models (Goh, 1998). Bowerman and O'Connell (1993) summarise the Box-Jenkins methodology as a four-step iterative procedure:

Step 1 - **Tentative identification**: stationary data series are used to tentatively identify an appropriate Box-Jenkins model by observing the behaviour of the ACF and the Partial ACF (PACF);

Step 2 - **Estimation**: historical data are used to estimate the parameters of the tentatively identified model;

Step 3 - **Diagnostic checking**: various diagnostics are used to check the adequacy of the tentatively identified model and, if need be, to suggest an improved model, which is then regarded as a new tentatively identified model. It is noted that user judgement and knowledge is still required at the stage of specifying model, analysis of seasonality and stationarity, and diagnostic checking;

Step 4 - **Forecasting**: once a final model is obtained, it is used to forecast future time series values

An ARIMA model is designed for stationary time series data, for which the process can be modelled via an equation with fixed coefficients that can be estimated from past data (Pindyck and Runbinfeld, 1998). For this reason, the periodic variations and systematic changes in the non-stationary data must first be identified and removed. The Augmented Dickey-Fuller (ADF) unit root tests mentioned in section 5.4.2 are used to check the stationarity of the data series as developed by Said and Dickey (1984) to ARMA models. The non-stationary series will be transformed by differencing into stationary one for ARIMA modelling.

The identified models are verified against the historical data for goodness of fit. The model presents a good fit when the standard error between the estimated value and historical actual value is small. In the cases of unacceptable performance of the specified model, the process would be repeated by using a different model until a satisfactory model is identified. In this study, the steps involved in the Box-Jenkins approach were carried out via SAS for PC.

The data series for ‘aggregate manpower demand in construction’ was first checked for stationarity using Augmented Dickey-Fuller (ADF) tests. The results of the ADF test reported in section 7.3.1 indicate that the time series of construction manpower demand is nonstationary, which was then transformed into a new time series that is stationary by the method of differencing. Therefore, the first differenced construction employment series is used in further ARIMA modelling.

```
                    The ARIMA Procedure

                  Name of Variable = D

Period(s) of Differencing                             1
Mean of Working Series                         0.004962
Standard Deviation                             0.036467
Number of Observations                               79
Observation(s) eliminated by differencing             1
```

```
                               Autocorrelations

Lag    Covariance    Correlation   -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1     Std Error

  0     0.0013299       1.00000    |                    |********************|            0
  1    -0.0000442       -.03324    |               .   *|    .               |     0.112509
  2    -0.0000423       -.03180    |               .   *|    .               |     0.112633
  3    0.00006465       0.04861    |               .    |*   .               |     0.112747
  4    0.00037213       0.27983    |               .    |******              |     0.113012
  5    -0.0001320       -.09928    |               .  **|    .               |     0.121466
  6    -0.0000981       -.07376    |               .   *|    .               |     0.122489
  7    0.00005125       0.03854    |               .    |*   .               |     0.123050
  8    -0.0001211       -.09110    |               .  **|    .               |     0.123203
  9    -0.0000832       -.06259    |               .   *|    .               |     0.124052
 10    -0.0000812       -.06109    |               .   *|    .               |     0.124451
 11    -0.0001735       -.13048    |               . ***|    .               |     0.124830
 12    0.00005424       0.04079    |               .    |*   .               |     0.126545
 13    -0.0001807       -.13591    |               . ***|    .               |     0.126711
 14    -2.3453E-6       -.00176    |               .    |    .               |     0.128543
 15    -0.0002059       -.15484    |               . ***|    .               |     0.128544
 16    0.00012465       0.09373    |               .    |**  .               |     0.130883
 17    -0.0000541       -.04068    |               .   *|    .               |     0.131730
 18    0.00003229       0.02428    |               .    |    .               |     0.131889
 19    -0.0002889       -.21723    |               .****|    .               |     0.131946

                         "." marks two standard errors
```

```
                      Partial Autocorrelations

Lag    Correlation   -1 9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 1

  1       -0.03324    |               .   *|    .               |
  2       -0.03294    |               .   *|    .               |
  3        0.04653    |               .    |*   .               |
  4        0.28320    |               .    |******              |
  5       -0.08095    |               .  **|    .               |
  6       -0.07415    |               .   *|    .               |
  7        0.00202    |               .    |    .               |
  8       -0.17699    |               .****|    .               |
  9       -0.01285    |               .    |    .               |
 10       -0.03852    |               .   *|    .               |
 11       -0.16685    |               . ***|    .               |
 12        0.12878    |               .    |*** .               |
 13       -0.15575    |               . ***|    .               |
 14        0.01519    |               .    |    .               |
 15       -0.09737    |               .  **|    .               |
 16       -0.00239    |               .    |    .               |
 17        0.03783    |               .    |*   .               |
 18        0.00587    |               .    |    .               |
 19       -0.25696    |               *****|    .               |
```

Figure E1 ACF and PACF of first differences of 'construction manpower demand'

At the model identification stage, the behaviour of the ACF and the Partial ACF (PACF) serve as the key to arrive at a tentative ARMA model. Figure E1 shows the ACF and the PACF of first differences of the series. These plots of the differenced series did not give a clear indication of an autoregressive (AR) or moving average (MA) model. Both ACF and PACF appear to cut off after lag 4, the closeness of fit for AR model (Equation E1) and MA model (Equation E2) were compared using Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC)[16] (Maddala, 2001). The model with smaller AIC/BIC values is retained. It is found that the AIC and BIC for MA model (-304.8, -300.1) is slightly smaller than those criteria for AR model (-302.1,

[16] If p is the total number of parameters estimated, AIC (p) = $n \log \hat{\sigma}_p^2 + 2p$; BIC ($p$) = $n \log \hat{\sigma}_p^2 + p \log n$, where n is the sample size.

297.3). For this reason, a tentative MA model (equation 6) was chosen for estimation.

$$Z_t = ø_4 Z_{t-4} + a_t \quad \text{(E1)}$$

$$Z_t = a_t - \theta_4 a_{t-4} \quad \text{(E2)}$$

where Y is the dependent variable, $Z_t = Y_t - Y_{t-1}$, $ø$ and θ *are* AR and MA coefficients respectively, a are the random error terms.

At the estimation stage, the tentative ARIMA $(0,1,0)(0,0,1)^4$ model was fitted to the differenced series and the model parameters were estimated using maximum likelihood. A hypothesis was conducted to test the inclusion of constant term in the model. It was observed that it was insignificant, indicating that this parameter might not be required. In addition, according to the results of the ADF tests, the single mean model indicates that the first differenced series is stationary without the trend deterministic term (i.e. βt). Therefore it is expected that the first differenced series would not have time trend to affect the ARIMA calculations. The MA model was then fitted without constant, the MA coefficient θ is found to be significant at the 5 % significance level. Then the equation for the best-fit model can be expressed as:

$$Z_t = \theta_4 a_{t-4}$$

where Z_t is the change of the target variable between current time t and $t-1$; the first-order moving average coefficient (θ_4) was found to be -0.4078; a_{t-4} are the random error terms at current time lag 4.

Diagnostic checking involved examining residual autocorrelation and Ljung Box Statistics to determine the adequacy of the fitted model. First, the residuals were checked for randomness by observing the pattern of the autocorrelations. The autocorrelation plot of residuals shows no pattern, thus indicating that the fitted model is adequate to explain most of the variation of the employment series. In addition, the Ljung Box Statistics of the residual autocorrelation coefficients equal to 6, 12, 18 and 24 are shown in Table E1. The high *p*-values reveal that there is no autocorrelation among the residuals of the model. Hence the random shocks are believed to be independent. From the above verifications, the fitted model adequately fits the data series for the aggregated construction manpower demand level in Hong Kong. The forecasts generated from this Box-Jenkins (BJ) model are compared with that from the VEC model.

To Lag	Chi-square	DF	Pr > ChiSq	--------------------Autocorrelations--------------------					
6	1.06	5	0.9579	0.002	0.003	0.037	-0.027	-0.093	-0.039
12	4.49	11	0.9535	0.085	-0.076	0.047	-0.040	-0.133	0.051
18	7.55	17	0.9752	-0.134	0.029	-0.018	0.095	0.036	0.039
24	12.14	23	0.9683	-0.194	-0.013	-0.029	-0.010	0.013	0.060

Table E1 Autocorrelation check of residuals for the construction manpower demand

APPENDIX H RESULTS OF MULTIPLE REGRESSION ANALYSIS OF BROAD OCCUPATIONAL SHARE MODELS

Managers and Administrators

The AUTOREG Procedure

Dependent Variable MANAGER

Maximum Likelihood Estimates

SSE	0.00142157	DFE	33
MSE	0.0000431	Root MSE	0.00656
SBC	-270.12606	AIC	-281.94822
Regress R-Square	0.4913	Total R-Square	0.5626
Durbin-Watson	2.0550		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	0.0301	0.8622	0.0126	0.9107
2	0.0726	0.9644	0.1975	0.9060
3	2.2456	0.5230	1.8287	0.6087
4	4.5994	0.3309	2.2851	0.6835
5	4.6085	0.4655	2.7143	0.7439
6	4.6170	0.5938	3.4191	0.7547
7	5.7107	0.5739	3.4344	0.8421
8	6.0321	0.6436	3.4639	0.9020
9	7.6301	0.5718	6.0360	0.7363
10	8.2567	0.6038	6.0379	0.8121
11	14.4510	0.2090	7.8237	0.7290
12	15.4033	0.2201	9.0832	0.6958

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	24	0.56	0.8437

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.4003	0.1365	2.93	0.0061
LNO_OTH3	1	-0.0663	0.0211	-3.15	0.0035
LNO_SPE1	1	0.0401	0.0103	3.89	0.0005
LNO_CIV3	1	0.0226	0.005178	4.36	0.0001
LNO_PUB4	1	-0.0284	0.009867	-2.88	0.0070
AR1	1	-0.3661	0.1696	-2.16	0.0382
AR2	1	0.3457	0.1642	2.11	0.0429

Professionals

The AUTOREG Procedure

Dependent Variable PROF

Maximum Likelihood Estimates

SSE	0.00031619	DFE	35
MSE	9.03389E-6	Root MSE	0.00301
SBC	-337.96287	AIC	-346.40727
Regress R-Square	0.8250	Total R-Square	0.8250
Durbin-Watson	2.0017		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	1.1565	0.2822	0.9844	0.3211
2	4.3678	0.1126	3.8120	0.1487
3	4.8288	0.1848	5.8444	0.1194
4	4.8410	0.3040	5.8448	0.2110
5	5.6821	0.3384	6.8226	0.2342
6	5.8550	0.4396	6.8890	0.3312
7	6.0272	0.5366	6.8990	0.4395
8	6.2299	0.6215	6.9674	0.5402
9	6.2525	0.7144	7.1419	0.6224
10	6.2622	0.7928	8.0368	0.6252
11	6.2686	0.8549	8.1340	0.7013
12	6.4984	0.8889	8.1420	0.7739

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	24	2.07	0.0645

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	-0.1067	0.0596	-1.79	0.0818
LNO_CIV3	1	0.0122	0.001986	6.13	<.0001
CEI_AVG1	1	-0.9013	0.1371	-6.58	<.0001
LNO_PUB	1	-0.0106	0.003291	-3.22	0.0028
LNO_Q2	1	0.0141	0.007409	1.91	0.0448

Associate Professionals

The AUTOREG Procedure

Dependent Variable TECH

Maximum Likelihood Estimates

SSE	0.00117653	DFE	35
MSE	0.0000336	Root MSE	0.00580
SBC	-284.48251	AIC	-292.92691
Regress R-Square	0.9537	Total R-Square	0.8945
Durbin-Watson	1.9956		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	1.3288	0.2490	1.1651	0.2804
2	2.2197	0.3296	1.8078	0.4050
3	2.3257	0.5076	1.8095	0.6129
4	2.4137	0.6602	1.8200	0.7688
5	2.6012	0.7612	1.9472	0.8564
6	3.0719	0.7998	2.0997	0.9103
7	3.9084	0.7903	2.5234	0.9253
8	4.0647	0.8512	2.5243	0.9606
9	4.0928	0.9052	2.6397	0.9769
10	4.7383	0.9080	4.4182	0.9265
11	4.7890	0.9410	4.5916	0.9493
12	4.9505	0.9596	5.0298	0.9570

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	26	0.33	0.9724

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.3224	0.0369	8.73	<.0001
CEI_AVG	1	-4.4094	0.1843	-23.93	<.0001
LNO_ARC4	1	-0.0200	0.003736	-5.34	<.0001
AR2	1	0.5082	0.1579	3.22	0.0028
AR4	1	0.3817	0.1609	2.37	0.0233

Craft and Related Workers

The AUTOREG Procedure

Dependent Variable CRAFT

GARCH Estimates

SSE	0.01188318	Observations	40
MSE	0.0002971	Uncond Var	0.00029708
Log Likelihood	105.67268	Total R-Square	0.8141
SBC	-192.90096	AIC	-201.34536
Durbin-Watson	1.7740		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	3.0120	0.0827	3.1844	0.0743
2	3.0384	0.2189	3.3425	0.1880
3	3.5234	0.3177	3.4024	0.3336
4	6.1693	0.1869	4.0888	0.3941
5	10.3669	0.0655	5.3142	0.3787
6	12.5205	0.0513	5.4308	0.4899
7	15.7819	0.0272	11.3959	0.1223
8	16.6413	0.0341	11.8223	0.1593
9	16.7039	0.0536	11.8696	0.2208
10	16.8122	0.0786	11.9089	0.2912
11	19.5484	0.0519	13.8071	0.2439
12	22.7963	0.0295	14.5632	0.2662

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	26	1.66	0.1403

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.1660	0.7517	0.22	0.8253
LNO_Q	1	0.0526	0.0026	2.01	0.0770
TIME	1	-0.003795	0.001767	-2.15	0.0317
AR1	1	-0.8891	0.0986	-9.02	<.0001
ARCH0	1	0.000297	0.0000714	4.16	<.0001
ARCH1	1	-8.22E-24	5.766E-12	-0.00	1.0000

Plant and Machine Operator/Assemblers

The AUTOREG Procedure

Dependent Variable   PLANT

Maximum Likelihood Estimates

SSE	0.00042767	DFE	34
MSE	0.0000126	Root MSE	0.00355
SBC	-322.115	AIC	-332.24828
Regress R-Square	0.5226	Total R-Square	0.6357
Durbin-Watson	1.9298		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	0.4715	0.4923	0.5535	0.4569
2	2.3744	0.3051	2.0911	0.3515
3	5.9001	0.1166	3.9047	0.2719
4	7.1072	0.1303	4.2810	0.3693
5	9.3382	0.0963	6.3237	0.2760
6	9.4502	0.1498	7.2502	0.2983
7	10.2258	0.1761	9.5497	0.2156
8	12.4055	0.1340	11.4742	0.1763
9	14.7050	0.0994	11.5228	0.2416
10	16.2476	0.0928	13.0586	0.2204
11	16.4732	0.1245	13.2227	0.2790
12	18.6911	0.0963	14.9656	0.2433

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	24	1.89	0.0933

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.0808	0.0537	1.50	0.1417
LNO_PUB3	1	0.0122	0.004433	2.76	0.0092
CEI_AVG2	1	-0.9343	0.2570	-3.64	0.0009
LNO_ARC1	1	-0.0233	0.006522	-3.58	0.0011
LNO_PI4	1	0.009967	0.003592	2.78	0.0089
AR1	1	-0.2744	0.1516	-1.81	0.0970

Clerks

The AUTOREG Procedure

Dependent Variable CLERK

Maximum Likelihood Estimates

SSE	0.0007404	DFE	37
MSE	0.0000200	Root MSE	0.00447
SBC	-311.30602	AIC	-316.37266
Regress R-Square	0.3863	Total R-Square	0.4863
Durbin-Watson	1.8365		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	0.4138	0.5201	0.4253	0.5143
2	0.5392	0.7637	0.8446	0.6555
3	0.5520	0.9073	0.8607	0.8349
4	0.5530	0.9681	1.0298	0.9052
5	1.0927	0.9547	2.5217	0.7732
6	1.5076	0.9590	3.3274	0.7668
7	3.4333	0.8422	6.1116	0.5268
8	4.0438	0.8532	7.8244	0.4508
9	4.4282	0.8810	9.3853	0.4025
10	6.6106	0.7616	10.5216	0.3960
11	6.8416	0.8118	10.6725	0.4711
12	7.2930	0.8377	13.3668	0.3430

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	26	0.90	0.5514

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	0.0497	0.002761	18.01	<.0001
CEI_AVG	1	-1.3641	0.3092	-4.41	<.0001
CEI_AVG4	1	0.8090	0.3378	2.40	0.0218

Elementary Occupations

The AUTOREG Procedure

Dependent Variable ELEM

Maximum Likelihood Estimates

SSE	0.00247883	DFE	32
MSE	0.0000775	Root MSE	0.00880
SBC	-244.09296	AIC	-257.60399
Regress R-Square	0.9015	Total R-Square	0.7796
Durbin-Watson	2.1171		

Q and LM Tests for ARCH Disturbances

Order	Q	Pr > Q	LM	Pr > LM
1	0.1114	0.7386	0.1077	0.7428
2	0.4442	0.8008	0.4489	0.7989
3	0.9498	0.8134	0.8456	0.8385
4	1.0256	0.9059	0.9685	0.9145
5	1.7365	0.8844	1.3252	0.9323
6	1.8575	0.9323	1.3956	0.9661
7	1.8943	0.9655	1.4080	0.9853
8	3.2309	0.9190	3.2537	0.9174
9	3.4972	0.9413	3.5821	0.9367
10	3.5246	0.9663	3.5995	0.9636
11	8.0279	0.7108	4.9930	0.9315
12	8.9896	0.7038	7.1191	0.8496

Structural Change Test

Test	Break Point	Num DF	Den DF	F Value	Pr > F
Predictive Chow	30	11	23	0.95	0.5516

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	-0.3104	0.0780	-3.98	0.0004
LN_CU1	1	0.0688	0.0139	4.93	<.0001
LNO_PI2	1	0.0178	0.004124	4.32	0.0001
CEI_AVG4	1	-4.2955	0.7198	-5.97	<.0001
CEI_AVG2	1	3.0767	0.7806	3.94	0.0004
LNO_ARC3	1	-0.0352	0.0102	-3.47	0.0015
AR1	1	0.3948	0.1625	2.43	0.0209
AR2	1	0.4019	0.1617	2.48	0.0184

APPENDIX I REVISED FORECASTING MODELS

Variables	Δd_t					
δ	-0.0014	(-0.2575)				
α	-0.4159	(-1.9527) #				
d_{t-1}	1					
q_{t-1}	-1.2446	(-22.3191) ###				
rw_{t-1}	-0.8008	(-6.9442) ###				
mp_{t-1}	0.4167	(6.1375) ###				
br_{t-1}	0.0403	(5.1492) ##				
lp_{t-1}	0.7553	(13.0810) ###				
ρ_0	-1.0637					
	t-1	***t-2***	***t-3***	***t-4***	***t-5***	***t-6***
Δ*d*	0.4669	0.4185	0.3974	0.8426	0.5343	0.1283
	(1.6495)#	(1.4153)#	(1.4408) #	(3.2934)##	(2.1399)##	(0.5658)
Δ*q*	-0.5702	-0.3161	-0.5571	-0.5848	-0.6739	-0.4364
	(-1.936)#	(-0.9709)	(-1.6798) #	(-1.9436)#	(-2.3298)###	(-1.9233)##
Δ*rw*	-0.1702	-0.0803	0.0587	0.0304	0.0899	0.1539
	(-1.2054)	(-0.6703)	(0.5169)#	(0.2822)	(0.8458)	(1.6490) #
Δ*mp*	0.1106	0.6529	0.3592	-0.6810	0.2662	-0.0584
	(0.2996)	(1.7531) #	(0.9509)	(-1.8176)#	(0.7096)	(-0.1693)
Δ*br*	0.0369	0.0390	0.0198	-0.0519	-0.0172	0.0555
	(1.6904) #	(1.7736) #	(0.8395)	(-1.9356)##	(-0.6419)	(2.1240) ##
Δ*lp*	0.4323	0.2070	0.3225	0.5560	0.4778	0.3193
	(2.1693)##	(0.9438)	(1.4876) #	(2.7253) ##	(2.3703)##	(1.8788) #

R-squared	0.5286	###	t-statistic significant at .01 level
Sum sq. resids	0.0480	##	t-statistic significant at .05 level
S.E. equation	0.0323	#	t-statistic significant at .1 level
Log likelihood	194.4700		

Note: *d*, $\log_e$ of manpower demand; *q*, $\log_e$ of construction output; *rw*, $\log_e$ of real wage; *br*, $\log_e$ (1+ interest rate); *lp*, $\log_e$ of labour productivity; values in parenthesis are *t*-statistics; sampling period: 1983Q1-2005Q3.

Table F1 Estimation results: vector error correction (VEC) model of the Hong Kong construction manpower demand (sampling period: 1983Q1-2005Q3)

Regression Models	**R^2**	**DW**	**NORM**	**CHOW**
$P_{ma} = 0.2819^{**} - 0.0738\, oth_{t-3}^{***} + 0.0525\, spe_{t-1}^{***}$ $+ 0.0210\, civ_{t-3}^{***} - 0.0200\, pub_{t-4}^{***}$ $+ 0.0040\, sf_t^{**} + v_t$ $v_t = 0.3241 v_{t-1}^{**} - 0.2973 v_{t-2}^{*} + \varepsilon_t$	0.5649	2.0407	0.0423 (0.9791)	0.70 (0.7410)
$P_p = -0.0474 + 0.0146\, civ_{t-3}^{***} - 0.9583\, CEI_t^{***}$ $- 0.0086\, pub_{t-3}^{**} + 0.0304\, q_{t-2}^{***} - 0.0258\, q_t^{**} + \varepsilon_t$	0.8206	1.9397	0.0873 (0.9573)	0.91 (0.5506)
$P_{ap} = 0.3209^{***} - 4.4066\, CEI_t^{***} - 0.0198\, arch_{t-4}^{***} + v_t$ $v_t = -0.4352 v_{t-2}^{***} + \varepsilon_t$	0.9255	1.7522	0.1644 (0.9211)	1.24 (0.2923)
$P_{cw} = -0.0149 + 0.0706\, q_t - 0.0030\, TIME^{*} + v_t$ $v_t = 0.9293 v_{t-1}^{***} + (0.000272^{***} - 7.62 \times 10^{-20}\, \varepsilon_{t-1}^{2})^{1/2} e_t$ $e_t \sim IN(0,1)$	0.8260	1.7852	1.4173 (0.4508)	1.47 (0.1401)
$P_{po} = 0.2265 + 0.0170\, pub_{t-3}^{***} - 0.9450\, CEI_{t-2}^{***}$ $- 0.0223\, oth_t^{***} - 0.0214\, arch_{t-1}^{***} + 0.0088\, pi_{t-4}^{***} + v_t$ $v_t = 0.3505 v_{t-1}^{**} + \varepsilon_t$	0.6700	1.9301	1.0310 (0.5972)	0.62 (0.8065)
$P_{ck} = 0.3377^{***} - 2.1584\, CEI_t^{***} + 1.2000\, CEI_{t-4}^{***}$ $- 0.0317\, oth_{t-2}^{***} + \varepsilon_t$	0.4410	1.9856	1.5192 (0.4679)	0.65 (0.7807)
$P_{eo} = -0.8567^{***} + 0.0623\, cu_{t-2}^{***} + 0.0455\, gen_t^{***} + v_t$ $v_t = -0.3001_{t-5}^{**} + \varepsilon_t$	0.5514	1.9218	2.2858 (0.3189)	0.59 (0.8354)

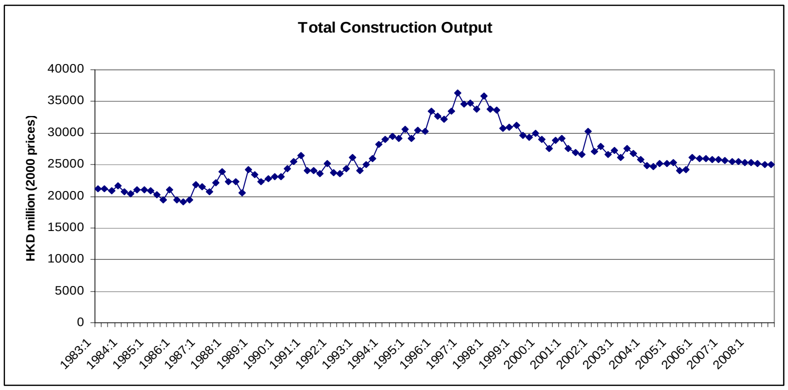
Note: *** t-statistic significant at .01 level, ** t-statistic significant at .05 level, * t-statistic significant at .1 level; P_i, percentage share for occupation *i*; ma, managers and administrators, p, professionals, ap, associate professionals, cw, craft and related workers, po, plant and machine operators and assemblers, ck, clerks, eo, elementary occupations; DW is Durbin-Watson statistic; NORM is Jarque-Bera test for normality of the residuals; CHOW is Chow's second test for predictive failure by splitting the data at 2nd quarter 1999; and figures in parentheses denote probability values;

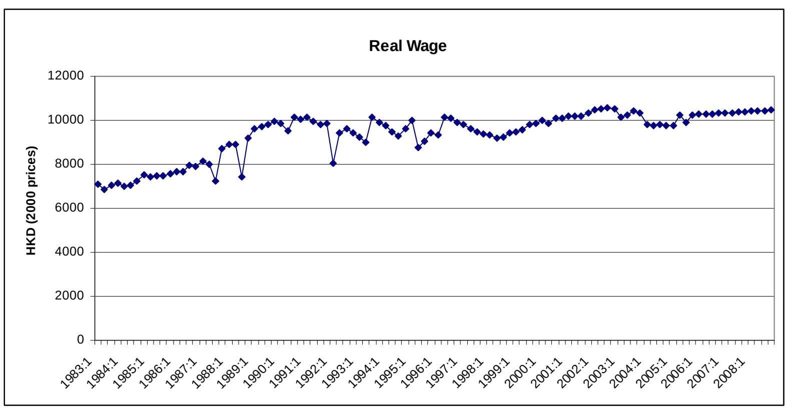
P_s	=	Percentage share for labour demand of occupation *s*
TIME	=	Time variable (1=1993Q1, 2=1993Q2…)
CEI	=	Capital to employment index
q	=	$\log_e$ of total construction output in HK$million
arch	=	$\log_e$ of construction output in erection of architectural superstructure
civ	=	$\log_e$ of construction output in civil engineering construction
sf	=	$\log_e$ of construction output in site formation & clearance
pi	=	$\log_e$ of construction output in piling & related foundation work
pub	=	$\log_e$ of construction output at the public sector
pri	=	$\log_e$ of construction output at the private sector
oth	=	$\log_e$ of construction output at locations other than sites for general trades and special trades
gen		$\log_e$ of construction output at locations other than sites for general trades (decoration, repair and maintenance)
spe		$\log_e$ of construction output at locations other than sites for special trades (carpentry, electrical and mechanical fitting, plumbing and gas work)
va	=	$\log_e$ of value added in construction

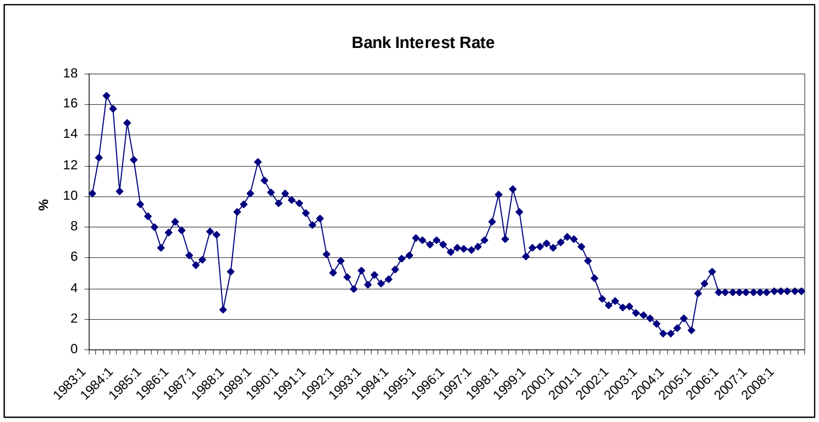
Table F2 Regression equations derived for the share of broad occupations (sampling period: 1983Q1-2005Q3)

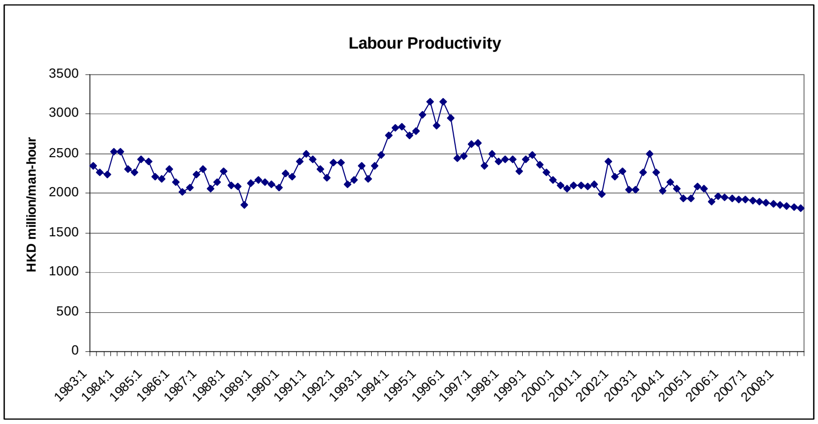
APPENDIX J FORECASTS OF KEY VARIABLES

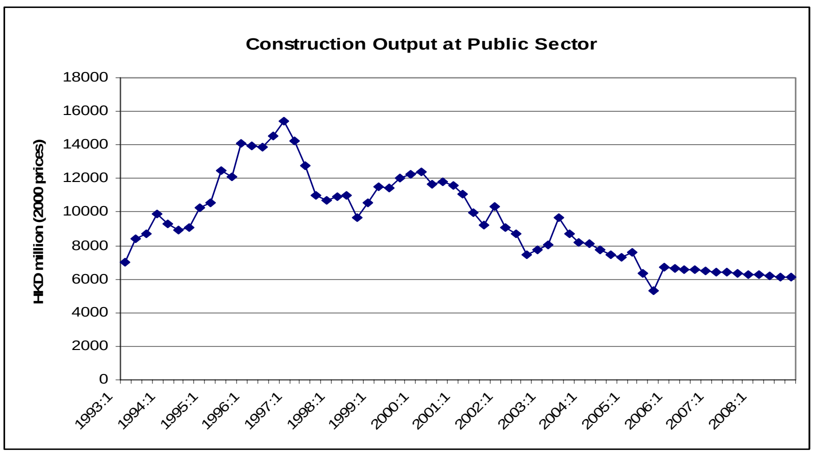
The estimates of the independent variables are required to yield the aggregate manpower demand and the share at broad occupational level. The initial forecast values for the independent variables over the *ex ante* forecasting period i.e. 2005Q4-2008Q4 are based on log linear trend extrapolation.

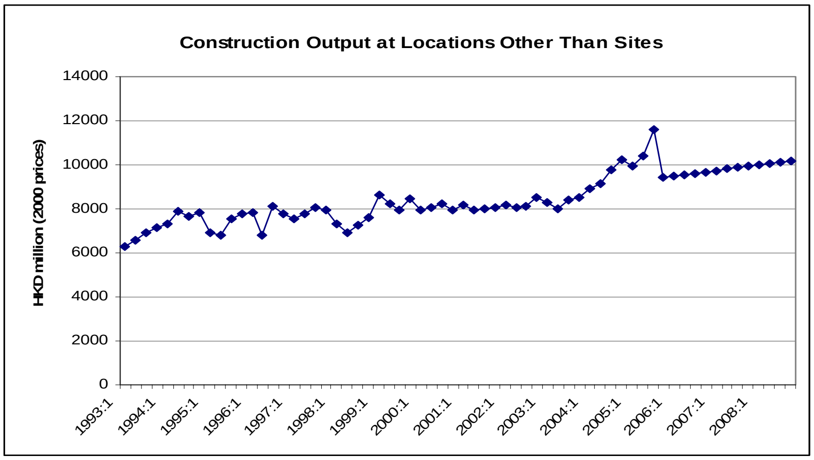


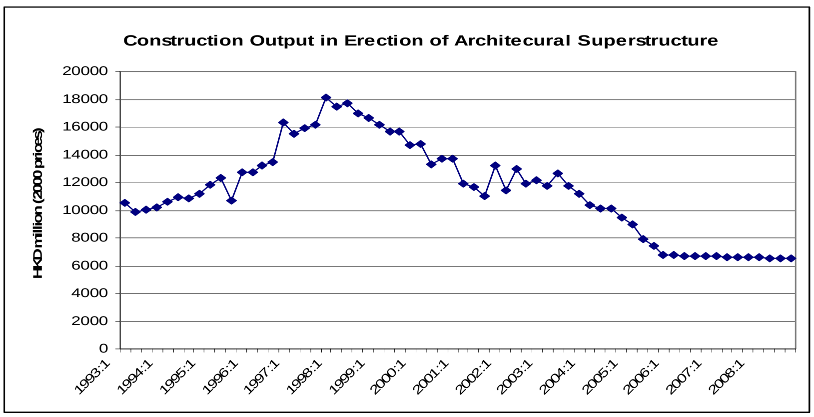


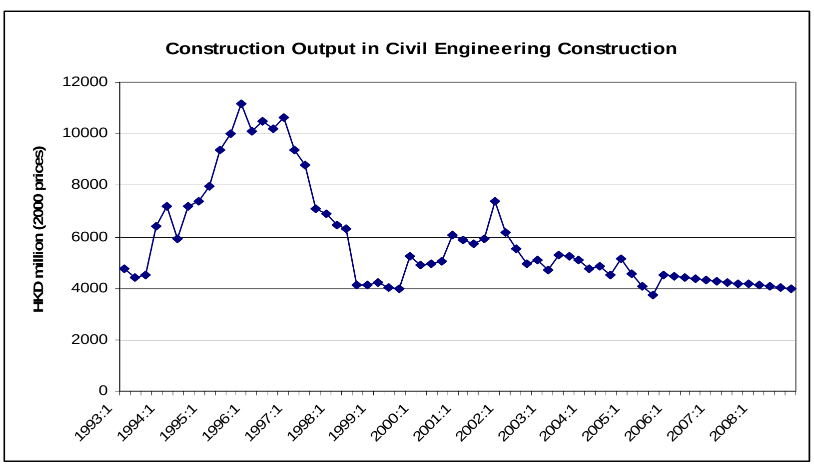

Bank Interest Rate
%
0
2
4
6
8
10
12
14
16
18
1983:1
1984:1
1985:1
1986:1
1987:1
1988:1
1989:1
1990:1
1991:1
1992:1
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1

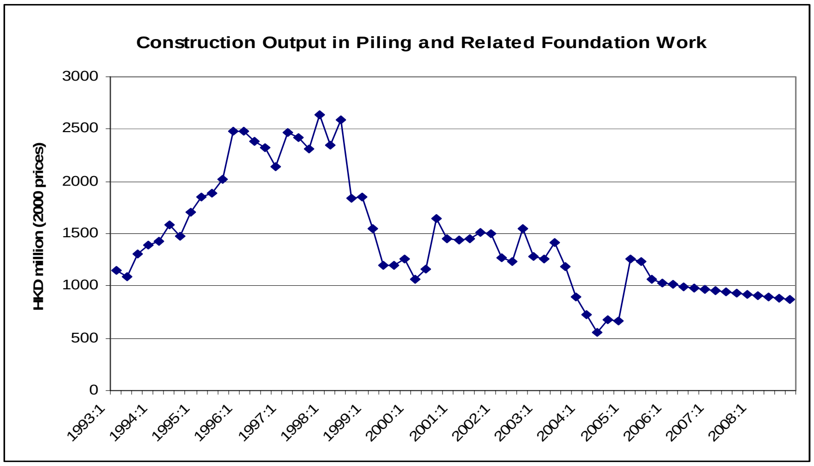

Labour Productivity
HKD million/man-hour
0
500
1000
1500
2000
2500
3000
3500
1983:1
1984:1
1985:1
1986:1
1987:1
1988:1
1989:1
1990:1
1991:1
1992:1
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1

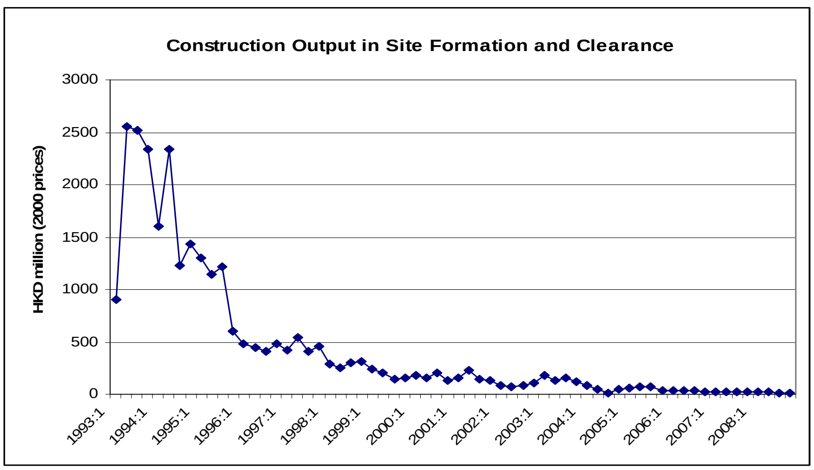

Construction Output at Public Sector
HKD million (2000 prices)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1

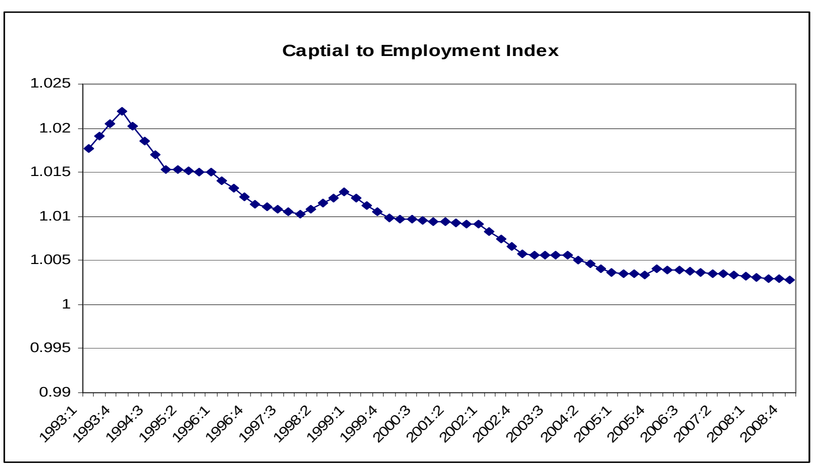

Construction Output at Locations Other Than Sites
HKD million (2000 prices)
14000
12000
10000
8000
6000
4000
2000
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1

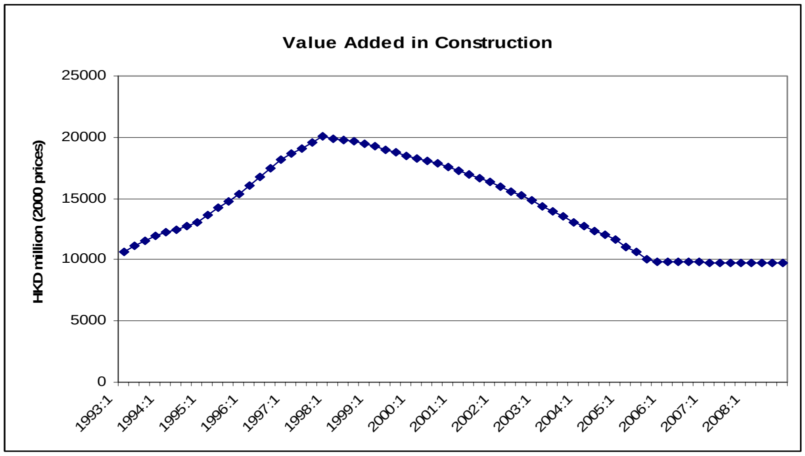

Construction Output in Erection of Architecural Superstructure
HKD million (2000 prices)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1


Construction Output in Civil Engineering Construction
HKD million (2000 prices)
12000
10000
8000
6000
4000
2000
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1


Construction Output in Piling and Related Foundation Work
HKD million (2000 prices)
3000
2500
2000
1500
1000
500
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1


Construction Output in Site Formation and Clearance
HKD million (2000 prices)
3000
2500
2000
1500
1000
500
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1


Captial to Employment Index
1.025
1.02
1.015
1.01
1.005
1
0.995
0.99
1993:1
1993:4
1994:3
1995:2
1996:1
1996:4
1997:3
1998:2
1999:1
1999:4
2000:3
2001:2
2002:1
2002:4
2003:3
2004:2
2005:1
2005:4
2006:3
2007:2
2008:1
2008:4


Value Added in Construction
HKD million (2000 prices)
25000
20000
15000
10000
5000
0
1993:1
1994:1
1995:1
1996:1
1997:1
1998:1
1999:1
2000:1
2001:1
2002:1
2003:1
2004:1
2005:1
2006:1
2007:1
2008:1